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ABBREVIATIONS. — D. = Discussion; I. = Illustrated.
Names of authors, etc., are printed in *italics*.

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CIVIC CENTERS AND THE GROUPING OF PUBLIC BUILDINGS, WITH A SUGGESTION FOR BOSTON.

BY STEPHEN CHILD, MEMBER BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read before the Society, November 20, 1907.]

THERE are on every hand cheering forecasts that a brighter day is dawning upon our American city life; that the fierceness of the rush and drive of the commercial whirlwind through which, as a nation, we have been passing, is somewhat abating, and though black and angry clouds lower upon the horizon, they are being broken up and dispersed by the bright sunshine of a more rational, a more peaceful and a more wholesome life, a life in which a more brotherly and neighborly feeling is growing, and in which all uplifting, moral and esthetic influences are having better opportunities for growth and development. While nothing can permanently darken or defer this brighter day to which we look forward, we may, by ill-considered and selfish actions, retard its progress. On the other hand, there are many influences over which we have direct control which may greatly hasten its arrival. Perhaps not the least helpful of these beneficent influences is the comparatively recent movement for a better civic art, better buildings both public and private; more numerous open spaces, adorned not only with flowers, shrubs and trees, but more frequently with fountains and other objects of art, such as properly located statuary, designed in an appropriate and dignified manner. The uplifting and inspiring influence of such artistic surroundings upon the community is very great, and they should be still further increased.

Much of the trend of civic improvement of late has been outward in ever-increasing circles, due largely to the wonderful development during the past twenty years in improved methods of rapid transit. Fearing that in this rapid growth we should be deprived of all our beauty spots, we have (and with reason here in Boston) been making great efforts and expending great sums of money to secure and develop large rural parks and scenic reservations, and to provide suitable parkway and boulevard approaches and connecting links for this great system. Far be it from me to decry the value of all this. On the contrary, I believe our city and metropolitan officials are to be congratulated upon the foresight and good judgment they have shown in securing and developing these most delightful features of our city, and that as time goes on it will be shown that they have proved of inestimable value to the health and morals of our community. Such features add to our fame and tend to attract not only visitors, but permanent residents of great value.

Possibly, however, we have gone far enough in this direction, for a time at least, and it may well be that a bit of introspection will do us good. May it not be that we need to study and reorganize the plan of the older and more thickly settled portions of our city with a view to securing more open spaces, and wider and more direct means of communication in the crowded portions of the city? Certainly in this study the grouping of needed public and semi-public buildings into so-called civic centers should be carefully considered.

The demand for a finer expression of civic art, especially in connection with our public buildings, is immediately confronted by the loss in dignity due to their widely separated locations, and it is becoming more and more evident that if such buildings can be grouped about a plaza or along a wide mall-like avenue in such a way that each building takes its proper place in harmonious architectural relation with other members of the group, each is enhanced in dignity and value. It has been asserted by a prominent architect that "isolated buildings of whatever individual merit are insignificant in comparison to massed constructions, even if these latter be comparatively mediocre in quality." It is evident that really fine buildings may be robbed of much of their impressiveness by being poorly located, crowded in among skyscrapers or more inferior buildings in such a way as to give little opportunity of seeing them, and almost no chance to appreciate their beauty. If beautiful buildings could only be grouped about a square or suitably pro-

portioned open space, how much more would they be admired and appreciated, and what a welcome addition would be made to our civic pride, now for many reasons almost extinct. I believe a finer public spirit would be aroused, and who shall say that as a result of this sort of publicity there might not be less of the corruption and so-called "graft" that now has such a good opportunity to flourish in our secluded and ill-placed public buildings? Nobody cares to go near them, and they are either so ugly or so inaccessible that many an intelligent, progressive citizen scarcely knows where they are, and never visits them unless he has to. Whereas if they were attractive and well-placed they would be more frequently inspected, and the "grafter" would feel that he was being more carefully watched than at present. Then, too, there is the great utilitarian gain in convenience if public buildings are grouped thus into administrative or civic centers, and a valuable saving in time for those having to transact public business by having them so massed.

I trust it will be interesting and profitable to study together for a few moments this evening what has been done in these respects in some European and American cities. The movement in this direction embraces most of the progressive municipalities of the civilized world, and, profiting by the mistakes of some of the older European cities, we here in America have been able to prepare plans, some of which are now in process of execution, which are distinct improvements over anything heretofore executed, except perhaps those at Paris and Vienna, and will make some of our American cities unrivaled in this respect.

Following a brief review of the more important of these developments, I will ask you to consider with me a suggestion in this respect for Boston, which I trust will interest you, as at least one of the many possible opportunities of making our city more dignified, impressive and inspiring.

While the movement toward securing civic centers and properly grouped public buildings is now receiving such well-deserved attention, and is sometimes spoken of as a new movement in civic life, it might more properly be referred to as a renaissance, for early historical research in the architectural development of cities shows us that such matters were very carefully considered in ancient times. Many of the celebrated early Egyptian communities show examples of this grouping, and in some instances the open spaces were embellished, as we know, with obelisks and other monuments. In some of these squares, or plazas, the shadow of the obelisk in the center marked the

passing hours upon the pavement, a suggestion worthy of our notice in the present day. In Assyria and Persia there are evidences that the grouping of palaces and temples was considered in very early times. But while we have some knowledge of these matters, the result of painstaking efforts of archeological students in Egyptian and Assyrian art, perhaps the most noted and certainly the most impressively dignified civic center of antiquity was the Acropolis at Athens.

In the prosperous days of Greece, when Athens was at the height of its power, civic pride and public devotion to public interests were very marked, and culminated in the notable aggregation of splendid structures grouped upon this noble hill. Even the ruins that have come down to us are magnificent. How much more so must have been the spectacle presented in the days of Pericles when every column was intact, every pediment and statue stood perfect and unmarred, the whole scene enhanced and made more beautiful by the brilliant atmosphere, Each building was nobly planned, not for itself alone, but in its relation to others of the group. What an impressive and inspiring sight it must have been, perhaps never excelled, and certainly an ideal toward which to strive.

The Greek genius was essentially and peculiarly artistic; that of Rome more especially political and administrative in its character. Rome conquered, administered and civilized the world of its time, founded modern civilization in fact, and while perhaps not creating a new art, developed and enriched other arts. The city of Rome became the center of all this administrative genius, and here about its Forum was built another grand civic center entirely different from that at Athens, but in its way equally impressive. Both the Acropolis at Athens and the Roman Forum afforded the people of these cities opportunty to mingle together, sharing their thoughts, their joys and their griefs. Here matters of the common weal were discussed and a broader public spirit developed.

After the decline of Greek and Roman influence, and during the so-called Dark Ages, little thought was given to any of these matters. Medieval cities were closely crowded communities, usually surrounded by fortified walls for the protection of the people from the attacks of wandering bands and neighboring feudal barons. Civic conditions were anything but attractive in these times. Streets were mere lanes, neither paved nor sewered. There were in most of these towns, market-places, however, and thanks to this provision, such communities now

possess an open square which has in more recent times been cleared of its booths and wagons, and embellished with planting, fountains and statuary, often making of it a most impressive and beautiful feature of the town's life. This development of the market-place has, however, come as a much later step. In medieval times these places were not cared for or improved, and there was no particular effort to group about them important public buildings, although the town-house and a church may have been built facing them. The great Gothic cathedrals suffered frequently from not being properly located and from being closely surrounded by low and unsightly buildings which mar the general appearance of these structures and prevent one's getting any adequate comprehension of their grandeur.

As warrings ceased and more peaceful times appeared, the towns and cities of Europe began to overflow the confines of their fortified walls and to spread out into the surrounding country. We shall see how the space occupied by these walls or bulwarks was later seized upon and utilized for great public improvements, for boulevards and civic centers, in Paris and other cities. In Vienna such space was developed into the magnificent Ringstrasse so-called, of which we shall hear more later. Let us look now at some of these civic improvements. Many of the views shown will no doubt be familiar to you, but I have endeavored to bring together the more important ones, and such as would have a bearing upon our problem here in Boston. Right here let me express my thanks to Professor Chandler, of the Architectural Department of Massachusetts Institute of Technology, and to Professor Pray, of the Lawrence Scientific School, and Mr. Fleischner, of the Boston Public Library, through whose courtesy I have been able to secure the lantern slides which I shall now be able to throw upon the screen. It may be interesting to turn back for a moment to Athens and Rome, to whose Acropolis and Forum I have already alluded.*

In no city in the world, perhaps, have better results been secured in this matter of the proper placing of buildings than in Paris. Here the public and semi-public buildings are almost always so placed or grouped as to enhance the appearance of one another and to provide pleasing vistas terminating the magnificent avenues. Perhaps the best and most famous example is the Louvre and Tuileries Garden. The Louvre is a civic center in itself. It is nearly 0.5 mile long and 0.25 mile

*Views of the Acropolis at Athens, and of Rome and the Roman Forum were here shown and commented upon.

broad. Part of this structure dates back to the sixteenth century, and the whole group contains some ten museums, besides the Ministry of Finance and that of Colonial Affairs. Many architects and sculptors have contributed to this harmonious group, which is generally considered one of the best works of French architecture.

Passing west of the Tuileries Garden, we come to the magnificent Place de la Concorde, one of the finest instances of plaza treatment in the world. From this the magnificent avenue of the Champs Elysées stretches westward, and a short distance in this direction we come to the modern civic center, where are grouped the Petit Palais and Grand Palais, two graceful buildings which are the permanent contribution of the Exposition of 1900. The avenue between these two palaces leads to the Alexander III Bridge, also a beautiful reminder of the same exposition. Returning to the Louvre, and just north of it, we find another civic center. Here are grouped the Ministry of Finance, the French Theater, and the Palais Royal, now used by the Council of State. Nearby is the Place de la République; also the Palace of Justice.

These are only a few illustrations of the way such matters are studied in this perhaps the most beautiful of modern cities, and no mention can here be made of the magnificent avenues, boulevards and parks.

The whole subject of civic art in Paris is placed in the hands of experts, and with the tireless energy of the French nation no such thought as that of standing still is ever considered. Progress toward better things is continuous. Every year sees plans for civic improvements made, which perhaps may be years in their execution, but which are all carefully studied, and when the need arises are ready for use. In this way few mistakes are made.

Next to Paris and, in fact, vying with it, if not in some respects excelling it in the grandeur of its civic improvements, is Vienna. Here the great space occupied by fortresses with their enclosing walls, and the open spaces formerly reserved for military drill grounds, becoming as they did, about the middle of the past century, not only of no avail for the original purposes for which they had been occupied, but a hindrance to the growth and development of the city, were, through the far-sighted and progressive good judgment of Emperor Francis Joseph, converted to the nobler purposes of magnificent civic improvements. The area formerly devoted to these warlike devices was so great,

and their value for many purposes so enormous (for they were situated in what was then near the center of the great city, and is now, in fact, well within what may be termed the heart of Vienna) that we may well imagine there was much discussion and no small contest over their ownership. The City of Vienna, the Kingdom of Austria, and the Crown Family itself, each laid claim to this territory, and as a result of this three-cornered contest the whole tract was set aside for the public's benefit; a portion of it that had been occupied by the old city wall was converted into a beautiful, broad, tree-lined boulevard or Ringstrasse, so-called; another portion was developed into parks just off from this boulevard, and forming magnificent foregrounds and settings for needed public buildings. The area to be utilized was so great that still another portion of it was reserved and under careful restrictions sold to furnish funds for building magnificent buildings and providing for their embellishment with suitable statuary, and so on.

We notice how the location of each building is carefully arranged so as to furnish an open space on at least one or more sides, so that its beautiful façades may be properly appreciated. We notice, too, the care with which buildings and monuments have been placed at vista points of the carefully-designed walks, streets and intersecting boulevards. Imagine the great and uplifting inspiration to the daily throngs of people passing and repassing these notable structures. What is particularly to be remembered is that these splendid effects have not been the result of chance, but have been brought about through the execution of most carefully thought-out plans, made with remarkable foresight some fifty years ago, and adhered to with a steadfastness of purpose greatly to the credit of the people of the Austrian capital. Would that some such steadfastness might inspire the law-makers of our own nation at Washington to adhere to and gradually and consistently carry out the magnificent scheme for civic improvement first planned by L'Enfant, Washington and Jefferson, over one hundred years ago, and now so happily revived and forming the inspiration for the plans of the so-called Burnham Commission. But more of this later.

Let us turn now for a brief inspection of what has been accomplished at Berlin. Probably the most famous single avenue of all Europe is that known by the name of Unter den Linden. The historic, patriotic and artistic sentiments of the entire German nation are centered here, and it is a civic center of great impressiveness. At the westerly end is the magnificent

Thiergarten, a fine public park of some 200 acres in extent, with its wonderfully impressive Sieges Allee, a beautiful feature. There are grand old trees, beautiful lakes and many other delightful objects of interest. Near here is the Brandenburg Gate.

At the easterly end of the avenue is the Spree Island, the older part of the city. (See Fig. 1.)* Here is an impressive group, including the Royal Palace and the Old Museum well placed about the open square known as the Lustgarten. Other beautiful buildings are grouped to the north of this, the whole island in fact being given up to public buildings, well-placed before open spaces, the latter parked and furnished with beautiful statuary, fountains and other embellishments. A rather modest bridge, but one well adorned with sculpture, spans the Spree and connects the island with the more modern city, and here the famous avenue Unter den Linden may be said to begin. On both sides for over two miles and a half are massive buildings, many of which are fine, and while some are of mediocre character, yet all are so skillfully grouped and interspersed with small parks like the Opern-Platz that the effect is one of dignity and repose. How much more impressive is this arrangement than if these buildings were scattered about the great city as is done in America, with no such effort to make each building serve its part in adding to the attractiveness of the others. May we not have our " Unter den Ulmus " here in Boston? I think we have the opportunity. One can well imagine with what watchful care any building proposed for this avenue is restricted, the emperor himself being given the authority to veto plans that do not come up to his high standards of beauty and symmetry.†

Let us now turn from European examples and look at what awakening America is doing in these respects. I think we shall be surprised, upon looking into this movement, to see what extent it has attained, and our self-complaisance here in Boston may be slightly shocked, perhaps to our advantage, when we see how our neighbors are improving their opportunities and we

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* For Figures 1–4, acknowledgment is due to the *Municipal Journal*.

† Several other views of Berlin public buildings were here shown and these were followed by views of the Kremlin at Moscow; the Nicolas Bridge and Square at St. Petersburg; St. Mark's Square at Venice; the Grand Palace and Gothic Hotel de Ville at Brussels; the spacious Zwinger at Dresden; the railroad station and square at Cologne; Trafalgar Square and the Thames embankment at London; also a plan of the new Kingshighway improvement there, — all illustrating interesting features bearing upon our own problems in Boston.

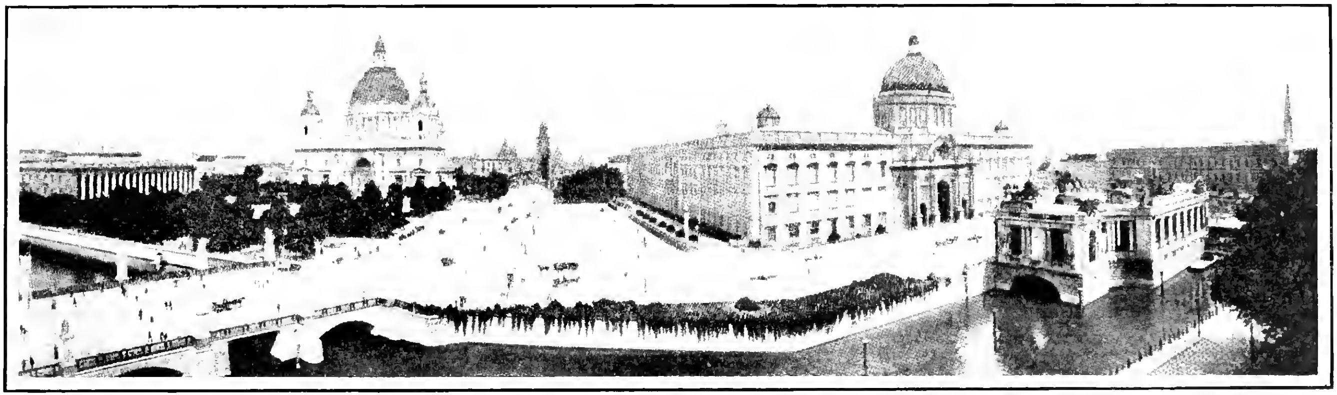


FIG. 1. A CIVIC CENTER AT BERLIN.

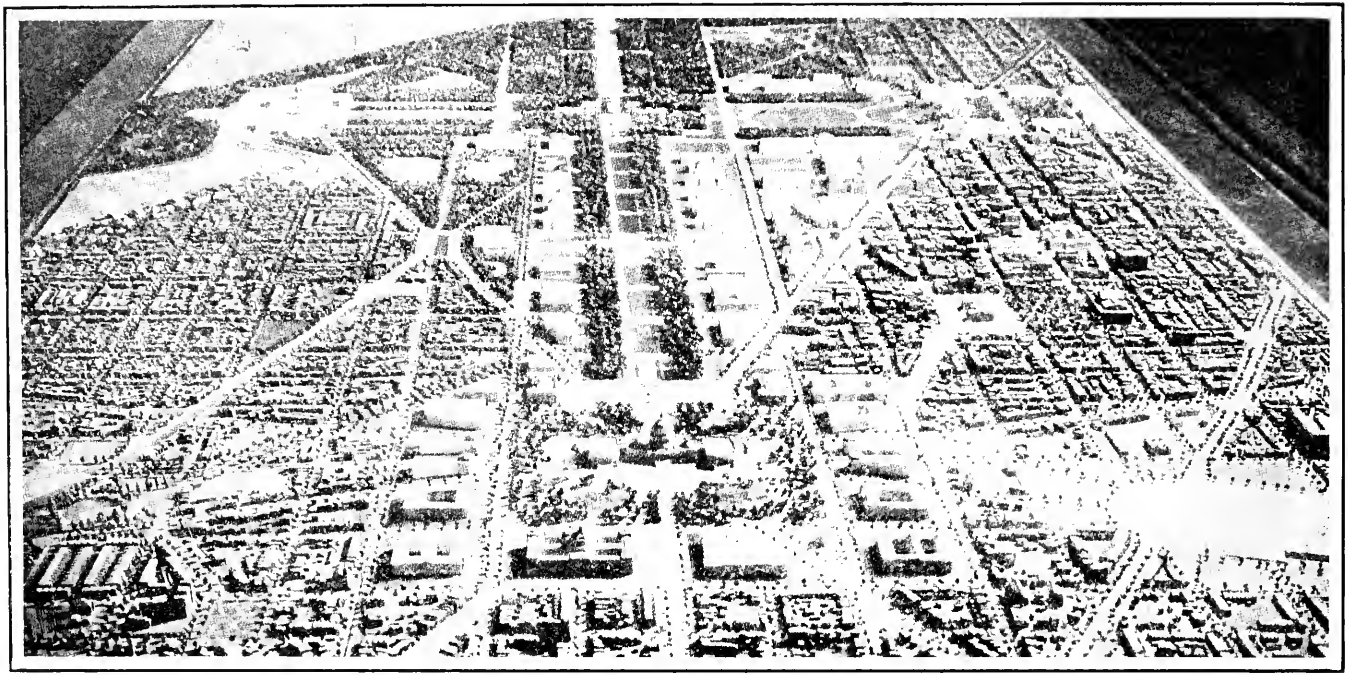


Fig. 2. Plan proposed for grouping Public Buildings at the National Capital.

are calmly letting ours slip by. Perhaps no one event has had a greater effect upon this question in this country than the World's Fair at Chicago in 1893. The inspiration of the wonderfully impressive massing and grouping of the beautiful and harmonious buildings of the Court of Honor is beginning to bear fruit in various ways. Hundreds of thousands of people saw and felt the value of this and carried the lesson to their home cities. Previous to this there had been in this country no concrete example to which we could refer, but now, thanks to this inspiration, we are beginning to find springing up all over this broad land of ours, wherever cities are prosperous and progressive, a desire, and in many cities a distinct movement, to accomplish something really inspiring and fine in the way of a group of public buildings.

1. *Washington.* — In perhaps no city has the Chicago World's Fair inspiration had a more marked effect than in the recent proposed improvements in Washington. Here, however, it must be borne in mind that the distinguished commission proposing these improvements was privileged to start with a really good city plan. It is a significant tribute to the genius of Major L'Enfant and to the good judgment of the commission (perhaps the most eminent group of specialists in this line in America, if not in the world), that, so far as the central portion of the city is concerned, the result of their thorough study, and a most careful inspection of the best European and other examples, has led them to unqualifiedly recommend the return to the original scheme as laid down by L'Enfant. The central feature of this scheme was "The Mall" (Fig. 2), and the commissioners have rescued this tract from the miserable state into which years of neglect had allowed it to sink, and legislative enactment has at last been obtained which will forever maintain this area for the purposes for which it was originally intended. Here will be laid out from the Capitol to the Potomac one of the grandest avenues, or set of avenues, in the world, flanking broad level lawns, shaded by noble trees and furnishing grand sites for the nation's public buildings.

2. *Cleveland.* — One of the first American cities to take up this important matter was Cleveland, Ohio. Here, soon after the Chicago World's Fair had closed, and while its influence was strongly felt, agitation was commenced upon the question of grouping in an impressive manner a number of public buildings of which the city stood in need. After some little preliminary discussion, the city government very wisely decided to place

this most important problem in the hands of an expert commission, with Mr. Daniel A. Burnham, of Chicago (the master mind in creating the Court of Honor there), at its head. This commission, after careful study of the whole problem, has issued its report, and its principal recommendations have not only been adopted, but much of the land has been condemned and progress made upon construction. When this work shall have been completed, " The Forest City of the West " will be able to offer to the world an example of impressively massed public buildings hardly possible to be excelled, certainly not at the present time. The experts here employed have recognized and incorporated in their scheme the two important existing elements of the lower portion of the city, the Central Station (the gateway of the present-day city) and the " City Square " (the terminus of the far-famed Euclid Avenue leading thence out to the magnificent residential and park districts of the city). A new station was a necessity, and it is now to be so placed as to form not only a magnificent gateway to the city, but the fitting terminus to the broad, tree-shaded and beautifully-proportioned mall leading to the City Square.

Along the mall, and so placed as to become harmonious parts of a most artistic composition, are to be grouped the desired buildings. Nearest the station, and separated from it by a wide tree-shaded esplanade, are the court house and city hall, and between them a grand fountain court. " The Mall," with its tree-shaded avenues, its grassed lawns and slopes, and its fountain basin, leads thence to the " City Square," and here are grouped the public library, the post-office, the Chamber of Commerce and other buildings, all to be of uniform and harmonious architectural design.

3. *St. Louis.* — Here a very interesting plan has been prepared by the Public Buildings Commission of the city for the grouping of a number of much-needed public buildings, two of which, namely, the public library and city hall, had already been started, with no thought of their relation to one another (Fig. 3). In the scheme proposed all the space between two north and south streets of the city is condemned and utilized as a mall, at the north end of which is the new public library, while at the southerly end is a civic plaza with the new city hall at one side, flanked by a much-needed new court house, and the whole scheme rounded out and completed by a building for a fire department headquarters, an administration building and a greatly-desired building for a police headquarters and jail. Each

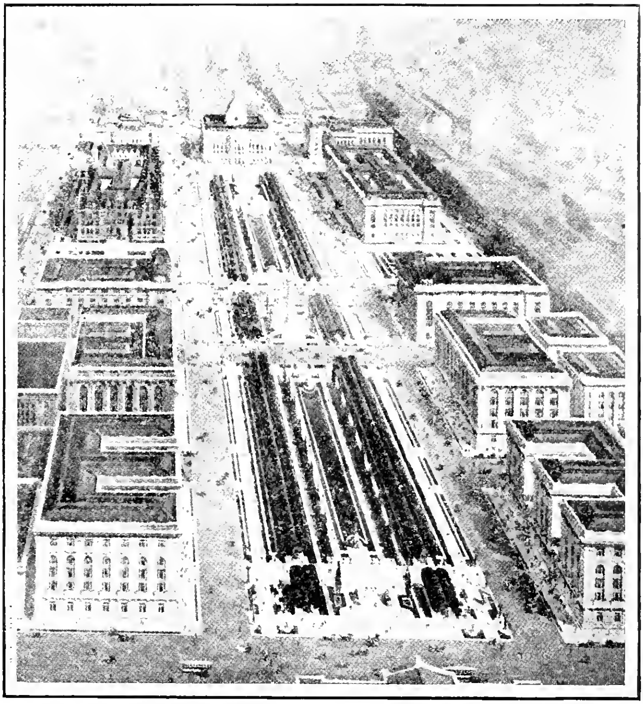


FIG. 3. PROPOSED CIVIC CENTER AT ST. LOUIS, MO.

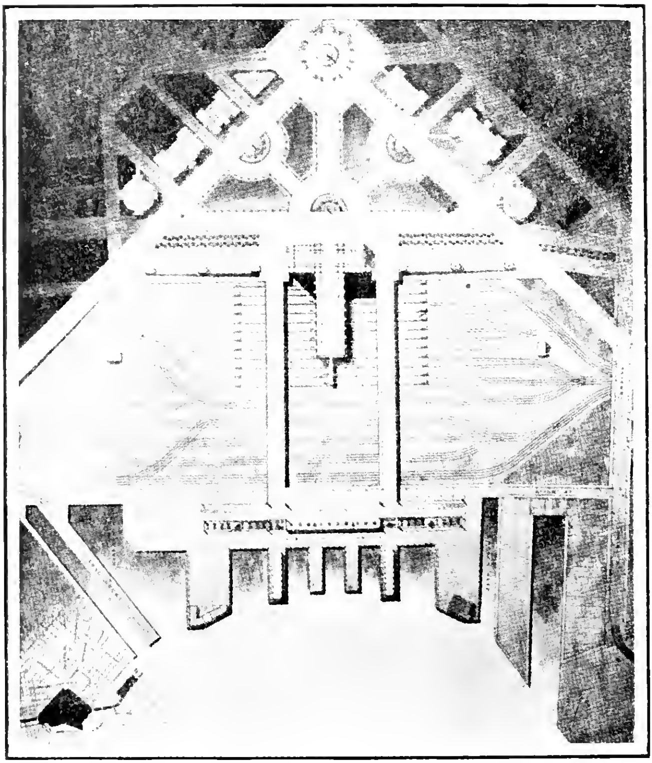


FIG. 4. PROPOSED CIVIC CENTER AT BUFFALO, N. Y.

of these will add to the beauty and impressiveness of the group, and when all are completed will furnish convenient and accessible housing for the city's business in a way that will add immensely to St. Louis's civic importance.

Along the mall and facing it would be most desirable sites for quasi-public buildings, such as theaters, hotels and the like. As the commissioners well say, " St. Louis has the opportunity, at a little more than the cost of the buildings, which are an immediate necessity, of securing a breathing space, a beauty spot and a scheme for present grouping and future development of which its citizens may all be proud." Since this plan was prepared another similar but less elaborate grouping has been submitted, either of which would greatly benefit the city's appearance.

Not only this, but far-reaching plans for river front improvements have also been studied and are in a fair way of adoption. Should Boston neglect its opportunities of like character?

4. *St. Paul.* — Here the new state capitol, which had been given a commanding site and appeared well from distant points, was almost lost in a maze of nearby streets and the crowding of houses about it, conditions not unlike those of our own State House. A triple radiation of avenues is now proposed that, when executed, will greatly add to the impressive appearance of this beautiful building from all of its principal approaches, besides bringing into the scheme, by means of one of these avenues, a fine new cathedral, and furnishing as well a splendid municipal court leading in the direction of the business district, upon which future city buildings will face. The third avenue, extending southward at right angles to the principal façade of the building, will furnish a most impressive approach from this direction. This avenue shows an interesting method of treating a steep grade which exists here, by means of skillfully arranged drives within a rectangular parked area, in the center of which a soldiers' monument is some day to be placed.

5. *Buffalo.* — Here we have a scheme for the grouping of public buildings about a plaza and parked extension of Niagara Square at the foot of Delaware Avenue, extending to the lake shore near " The Terrace " (Fig. 4). This will provide fine sites for a number of needed public buildings, will insure a much more beautiful setting for the present city hall, which is brought into the scheme, and will also furnish a site for a proposed new union station on the lake shore. In this connection an interest-

ing feature is the provision for a loop track, so that trains coming into Buffalo may pass around this loop and thence out of the city, thus avoiding the inconvenient and confusing switch-back arrangement now in use. One gentleman is largely responsible for this movement, and has, I believe, even gone to the expense of securing options on much of this land, and the scheme is likely to go through. The railroad contemplates spending some $15 000 000 and the city between $5 000 000 and $10 000 000 more.

6. At *Philadelphia* a wide new avenue is proposed and the land condemned, extending in a straight line from the city hall to the principal entrance to Fairmount Park. This will cost perhaps $5 000 000, but will well repay this expenditure in the increased beauty, dignity and convenience which it will afford. It will greatly add to the impressiveness of the magnificent city hall and will make the park system much more accessible.

7. *New York.* — The Municipal Art Society of the City of New York, through its Committee on Civic Centers, has issued a report containing an interesting plan for the development of a magnificently impressive civic center at City Hall Square. The existing very beautiful city hall building is preserved and given a much more fitting setting by the removal of all the other more or less inferior buildings that now encumber the square, including the very ugly post-office building. All the existing buildings on the northerly side of Chambers Street are removed and replaced by those of a more monumental character, to be utilized for the housing of the various departments of the city's business. The plan calls for a more adequate arrangement for the handling of the immense throngs that utilize the Brooklyn Bridge terminal here, and in this connection a colossal towering structure will balance the existing skyscrapers of Park Row and Broadway nearby and furnish apparently ample office accommodation for New York's city officials for years to come. At Brooklyn a grand plaza has been proposed, so located as to be the point of meeting of avenues leading thence to the East River and Manhattan bridges, and serving thus to amply connect the heart of this great borough with Manhattan Island, diverting and controlling the immense traffic to and fro, and offering as well grand sites for the various office buildings of the borough of Kings County. Time and space allow for but the briefest glance and mention of the other improvements of a similar nature proposed for the civic betterment of this great metropolis. These include the Battery Park improvement, a subway loop terminal for

the new Blackwell's Island bridge, the proposed Chelsea improvements with an elevated roadway on West Street, a widening of 181st Street and many other changes in Manhattan and the Bronx.

These are but a few of the more important cities that are undertaking, or at least planning, improvements of this sort. Others that might be mentioned are San Francisco, Oakland and Los Angeles, Cal.; Denver, Colo.; Columbia and Greenville, S. C.; Montreal, Canada; and even far-away Honolulu, Manila and Rio Janiero.

Boston. — With these examples before us of what has been and is now being accomplished, let us see what our own city has to offer in the way of possibilities. We shall find a number of such opportunities awaiting development. We have seen that, as in Paris, Vienna and Berlin, every large city has or may have several civic centers, and that in the best and most comprehensive design these all bear a certain relation to one another and are bound together by well-arranged avenues or boulevards into an effective city plan, so here in Boston we have several opportunities for effectively grouping our needed new buildings into impressive civic centers. At Copley Square will undoubtedly be one; at Park Square perhaps another. Much of our artistic and musical life is moving out toward the Fens, and there is growing here what will eventually be another important grouping of beautiful buildings. Suggestions for an improvement of conditions here have recently been made in the report of the Committee on Municipal Improvements of the Boston Society of Architects. This valuable report also brings out such interesting suggestions as an island in the Charles River Basin; a fitting plaza treatment for the terminus of Commonwealth Avenue at the Public Garden; this latter in connection with proposed widening of Arlington Street and its extension south of Boylston Street to Shawmut Avenue, with a city hall site at Tremont Street opposite the Castle Square Theater.

The most striking feature of our city, however, is Beacon Hill, which, with its noble, gilded-dome State House, dominates the community and is the cynosure of all eyes. It is my belief that this central feature of our city has as yet been too little appreciated, and that a plan may be developed which shall fittingly recognize this hill, and as a result provide for our State House a more dignified setting, with opportunities for its enlargement; also sites for many much-needed buildings, and a desirable connecting link in our parkway system at the same time.

Some twelve or fourteen years ago Charles Eliot, one of the elder Olmsted's gifted disciples, proposed an improvement to Boston's water-front and the mouth of the Charles River which involved, among other desirable things, the removal of the North Station to the Charlestown side of the river. My attention was attracted to this plan a few years ago, and to the fact that such a change would offer opportunities for grouping public buildings here on the water-front in an impressive and dignified manner. Let me quote from a letter written by Mr. Eliot at that time to the Joint Board for the Improvement of the Charles River. This letter was not published until about five years ago, when it appeared in the account of his life, edited by his father, President Eliot of Harvard University:

"At the northern end of the basin (see Eliot plan, Fig. 5), that part of the river which lies between East Cambridge, Charlestown and Boston is choked by innumerable piles supporting railroad bridges. The cost of space for a suitable Union Station on the mainland of Boston being very great, the railroads have contrived to obtain permission to cover the river with a timber platform which they use as a rent-free switching yard and terminal. It is well known that, in view of national and state legislation, this virtual obliteration of the river by the railroads is only temporarily permitted. When the renewal of this permission shall be at last refused, the railroads will be compelled to place their terminal station on the north bank of the Charles River, presumably about in the position indicated upon the plan. By this arrangement the breadth of the stream will be restored and the banks and bridges will become susceptible of fine architectural treatment.

"As compared with the present stand, this new station will be distant from the corner of Washington and Summer streets about half as far again; from Copley Square it will not be farther distant than the present station, and the route to it by way of Dartmouth Street and the banks of the Charles will be much more agreeable than the route through the city which is followed to-day. In this connection the plan suggests an improved position for the future bridge to Charlestown and a way of entrance into the city for a boulevard leading from the northern suburbs by way of Sullivan Square, Charlestown, to both Lafayette Square, Cambridge, and the Back Bay."

You will note that the plan herewith submitted (Fig. 6) modifies this suggestion somewhat, for it seemed to me desirable, upon more careful study of all conditions, to go a step further, and, by means of a wide avenue with tree-shaded malls, connect our State House and Common with this water-front improvement. The scheme here presented, then, comprehends, as you

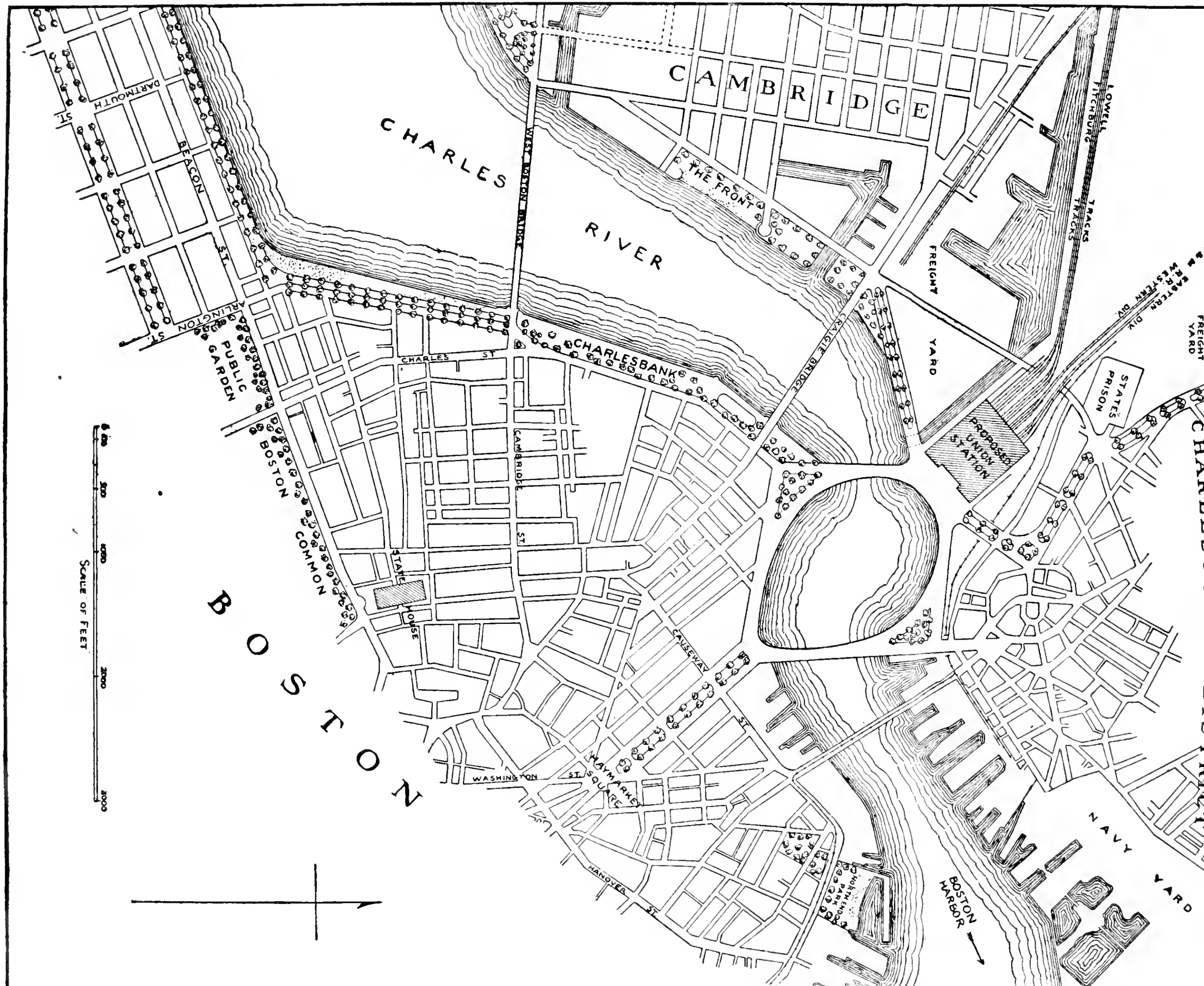
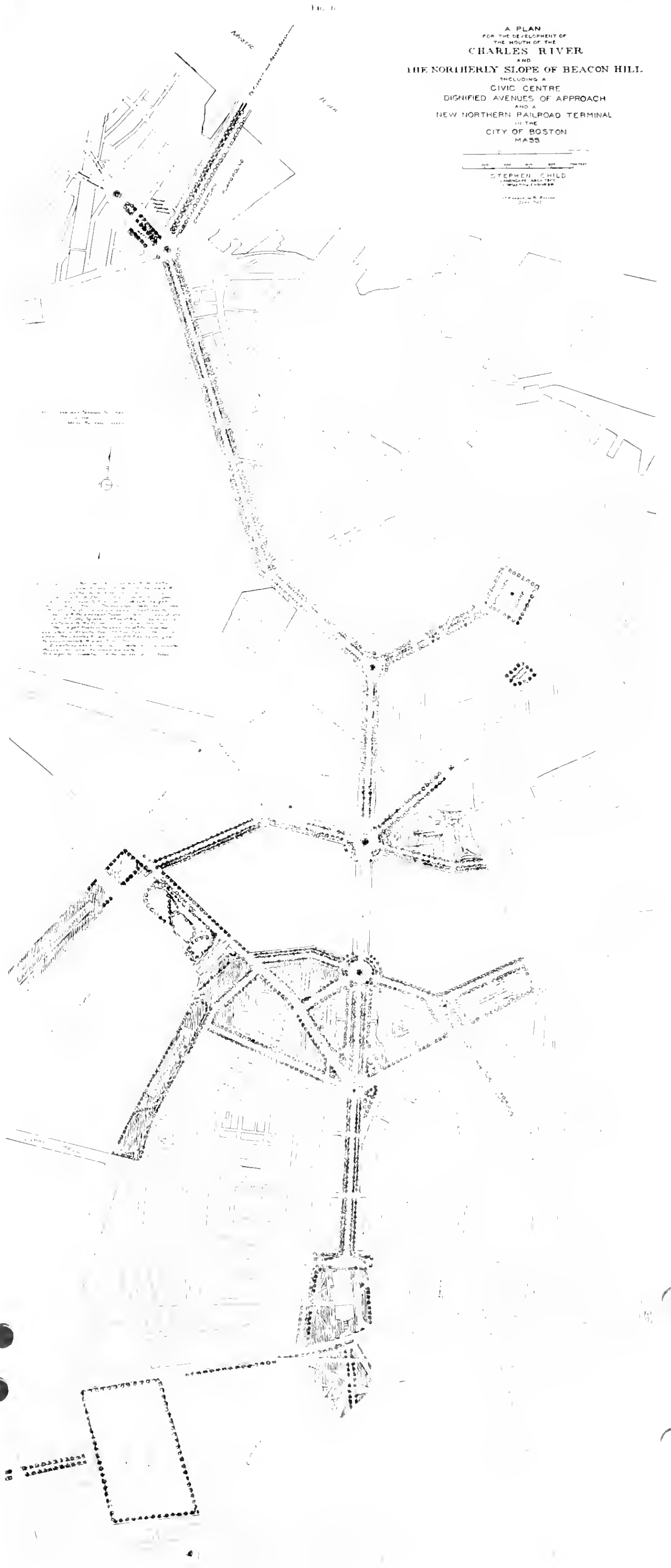


FIG. 5. (REPRODUCED BY KIND PERMISSION OF PRESIDENT ELIOT.)


A PLAN
FOR THE DEVELOPMENT OF
THE MOUTH OF THE
CHARLES RIVER
AND
THE NORTHERLY SLOPE OF BEACON HILL
INCLUDING A
CIVIC CENTRE
DIGNIFIED AVENUES OF APPROACH
AND A
NEW NORTHERN RAILROAD TERMINAL
IN THE
CITY OF BOSTON
MASS
STEPHEN CHILD
LANDSCAPE ARCHITECT
CONSULTING ENGINEER
MYSTIC

will see, in a general way, the development of the north slope of Beacon Hill and of what might be termed the "Lower Charles River Basin," and, therefore, supplements and completes the magnificent development now going forward above the new dam at Craigie Bridge. It recognizes Beacon Hill and the State House as the crowning feature of our city, and provides not only a more dignified and adequate setting for this noble structure, but opportunity for its enlargement, as well as sites for a number of other much needed buildings to be built from time to time, and for a new North Station. Furthermore, it secures to our citizens what has long been wanting, namely, a means of reaching, in an agreeable manner, the Middlesex Fells and the Revere Beach reservations of our Metropolitan park system. The scheme provides a monumental tree-shaded avenue, which starts from Boston Common and the State House and proceeds northerly down the slope of Beacon Hill in a direction parallel with existing lines of streets, and so arranged that the dome of the State House and the beautiful north façade of that building are both recognized and can be thoroughly appreciated by those approaching from the north. What is actually proposed is the wiping out of all of the existing structures between the easterly street line of Temple Street and the westerly street line of Hancock Street from Derne Street, at the rear of the State House, down to Cambridge Street. A strip of land approximately 200 ft. wide is thus secured, which could be subdivided as shown, for an avenue or parkway, and its extension in a direct line northerly will almost exactly coincide with the existing easterly line of Staniford Street and the westerly line of Lynde Street. It is to be noted that within this area there are almost no buildings of very great value. I have suggested a subdivision of this 200-ft. strip as follows: In the center a 50-ft. avenue for pleasure driving only, flanked on either side by wide malls, tree-shaded, and affording ample opportunity for agreeable promenades and for viewing the pleasure driving of the central avenue. On either side of these tree-shaded malls are 25-ft. roadways for the service of the adjacent property and for teaming and all such traffic, and in addition space for an ample sidewalk, 12.5 ft. wide, adjoining the property lines. On the right and left of this avenue would be sites for future properly restricted buildings. State House growth might well be provided for here. The avenue would broaden out into a wide circular plaza at the river's mouth upon which may front, in a dignified and adequate manner, appropriate to a maritime city of Boston's importance, public

buildings, of which I shall speak in more detail later. This avenue would continue in a direct line by a monumental bridge over the lower Charles River Basin to another broad plaza similar to that at the southern end of the bridge, and upon this plaza would face the proposed new North Station. In some such way we could secure a fitting and dignified entrance to our city for the thousands of travelers and commuters entering from the north, and give them an opportunity of seeing and appreciating our noble State House as well as other public buildings.

Continuing with the general features of the plan, we see that the avenue, somewhat narrowed now, passes by a raised viaduct over the tracks of the branch railroad to the Hoosac Tunnel docks and the Navy Yard and over other important freight facilities (which would by this means be entirely undisturbed) to a circle and vista point from which avenues separate; that to the east providing (what is now much desired) an agreeable means of driving to Bunker Hill Monument, and that to the north, by a widening and parking of Rutherford Avenue, furnishing a parkway leading through Sullivan Square, redesigned and improved, and thence proceeding either by Broadway or Mystic Avenue (widened and parked) to Broadway Park, Somerville, whence there is now a beautiful parkway approach to the Middlesex Fells. From Sullivan Square an avenue should be studied leading to the east, past the Charlestown playground and crossing the Everett Bridge by way of Broadway, widened and parked, meeting the new Revere Beach parkway at Everett, thus furnishing an agreeable means of reaching this popular reservation from the heart of the city — a desirable improvement.

So much for the general features of the plan. A brief consideration of some of the more important details may be of interest. The first and perhaps most important to great numbers of our citizens is the proposition to move the North Station across the river. I can almost hear some of our practical friends saying, "Why move our station farther away? We want greater convenience, not less." Very true, and if utility and convenience were the sole considerations, perhaps it would be well to tunnel under our city from both north and south, and, coming up at the Common, build there a great union station for all the roads entering Boston. I am afraid, however, in spite of the convenience derived, public sentiment would hardly sanction such a desecration of our sacred Common. I trust not, for I believe there is a better solution. We have seen that as far back as 1894 thoughtful people were proposing the relocation of

this station at about the point here shown, and there is no doubt that the arguments then advanced still hold good and can be reinforced by others. No one doubts that the railroads are simply permitted to encumber the river here with " innumerable piles and bridges " and to utilize these timber platform, switch yards and terminal facilities " rent free." Neither is it to be doubted that such permission has been of incalculable value, not alone to the railroads, but to the great community which they serve. That at some day not long distant national and state governments will undoubtedly withdraw these permits can hardly be doubted, especially if it can be shown that great improvements to our city can thus be accomplished. But convenient and liberal provisions for terminal facilities are of such vital importance to the well-being of the entire community that projects for changing them should not be entered upon lightly or without offering distinct improvements over those now existing.

When such improvements can be demonstrated, however, it has been the universal experience that there are no more progressive and liberal-minded people in the world than the presidents and directors of our great railroad systems, and the enormous sums of money that they are to-day expending to secure not simply adequate, but monumentally attractive terminal railroad stations in the great cities of this country alone (not to mention Europe), are almost incredible. We have already alluded to some of these. At Washington, for example, a $3 000 000 white marble station is in process of erection, to be reached by tunnels, and one of the most gratifying things in the situation there was the fine spirit with which the late President Cassatt and the Pennsylvania Railroad directors met the suggestions of the improvement commission. For it must be remembered that the Pennsylvania Railroad owned and occupied fifteen or twenty acres of land upon which were located a station and terminal yards directly in the way of the proposed mall improvement.

We have seen what the Lake Shore Railroad has been willing to do at Cleveland, what the New York Central is to do at Buffalo. We hear of new $30 000 000 terminal facilities to be provided for Chicago, and we know of the $10 000 000 Pennsylvania Railroad station in process of construction in New York, and now comes the New York Central, after only a few years' use of a completely remodeled station at Forty-second Street, and proposes to tear that one down; replacing it by a more

commodious and certainly much more beautiful structure, a great ornament to the city and added proof of the progressive and liberal spirit of that great corporation. In addition to this, and as a part of the scheme for the new Grand Central Station, a temporary one at an expense of $200 000 will have to be erected and later torn down. Undoubtedly none of these great undertakings are entered upon without a careful consideration of the cost and of the probable return to the corporation interested. Let us see whether there may not be some such factors that will be of interest to the Boston & Maine system and its thousands of patrons by our proposed move. Practically considered, the present station is already overcrowded, leaky and poorly ventilated. The delays due to the congestion of traffic at the drawbridges are expensive and annoying. The station is, to say the least, not an ornament to our city, nor a fitting terminal for one of the great railroad systems of America. The move proposed is in a direction that will involve as slight an expenditure of money as any that could be suggested, perhaps, for it would place the station where it would conveniently receive all the various divisions of the system without necessitating a narrowing up of the trackage facilities for the purpose of crossing any bridge or similar obstacle. It is in fact here located (see plan) just south of the point where all the tracks now meet; but, we are told, it removes the patron just so much farther from the heart of the city. Charles Eliot has already told us how comparatively little this would amount to, but let us see if modern engineering achievements may not obviate even this difficulty. What good reason would there be, for example, why the various railroad systems entering Boston should not be allowed, under proper restriction, to tunnel the city from this new North Station to the South Station, and build a subway (see line on plan) to accommodate (as will the Pennsylvania Railroad tunnels in New York) not only passenger but freight traffic, thus relieving the crowded and circuitous "Grand Junction" freight line from Cottage Farm to Charlestown, and thereby also helping to solve the knotty problem of the Brookline Street bridge at Cottage Farm.

A tunnel as here suggested could be arranged so that its passenger tracks could have one or more connections with our subway system in the city. It would then be possible for a passenger arriving from the north to do either one of several things. He could stretch his travel-cramped limbs by a delightful walk across an imposing plaza and bridge, getting a fine

first impression of our city, with views of monumental city buildings and of the shipping in the foreground, unmarred by any hideous elevated structures. He could, if so disposed, continue his walk (perhaps lured by the gilded dome of the State House) up a wide tree-shaded mall to the Common; he could follow the river bank on either side by tree-shaded promenades to the beautiful Charles River Basin, the Charlesbank and Riverbank parks. If he were not so actively disposed he could enjoy all this from a carriage and drive on out into the park system in either direction.

If, on the contrary, he is a hurrying commuter or a rushing traveling man, he can go down a flight of steps, or better yet an elevator, and take a car that will whisk him under the city, leave him if needs be at Scollay Square, Park Street or Summer Street, or rush him through to the South Station in say five minutes' time, amply sufficient to catch his New York or Chicago express, or transfer to a suburban service train for Brookline or Newton. Furthermore, this plan would offer to the railroad company certain definite opportunities for reimbursing themselves to a considerable extent for the outlay. The land now utilized for station and yards would have a value to the city or county for its buildings. The improvement to the waterfront, the bridges, parkways, and so on would enhance this value. Not only that, but the region to the west of the proposed new station, now a freight yard, might become the site of warehouses that would rival those at South Boston (Woolville so-called) in business facilities. Here, with fine railroad accommodations, and with Miller's River widened and deepened offering shipping facilities, and with upper and lower roadways, the lower connecting the shipping passages with the basement floor of these buildings, this territory would be of great commercial value and a source of revenue to its owners. The great foresight of this railroad system in already securing the old McLean Asylum grounds gives them the needed chance to expand and accommodate their constantly increasing freight-traffic needs in this direction. It is a noticeable fact also that the present railroad buildings on the north side of the river here are all of them old and most of them of a distinctly temporary character and of little intrinsic value, and it will, therefore, not be a great sacrifice to do away with them, replacing them a little farther out, say on the old asylum grounds, by up-to-date structures more efficiently planned for modern needs. There is nothing in these arguments that would in the least interfere with the proposed

merger of the Boston & Maine system with the New York, New Haven & Hartford, and indeed much that might be advantageous to such a proposition.

Assuming, then, that these advantages are sufficient to warrant this move on the part of the railroad company, what can be said in favor of utilizing the territory thus made available for a grand civic center? Boston, the chief port of New England, famous for its maritime history, should look to the development of its water-front, and what more appropriate location could be suggested than this for its chief city buildings. The crying need for a new and commodious City Hall has been admitted for years. Commissioners are now investigating the crowded condition of the State House and of Suffolk County Court House; our various metropolitan commissioners are now housed in scattered office buildings for which the community pays large sums in rentals. A new custom house and appraisers stores is proposed; why not, then, proceed in a thorough manner to wipe out the crowded slum district hereabout, providing carefully for model tenements elsewhere, and set aside this water-front region for the buildings so much needed? Here they can be conveniently grouped in a dignified manner, perhaps in some such general way as is here suggested, and, with the proper architectural treatment of buildings, grounds, plazas, avenues, bridges and abutment walls, give to our beloved old city a magnificent approach and an administrative center of which we could really be proud.

There is much talk of the need of economy in public expenditures, and no doubt it is greatly to be desired, but I believe the expenditure involved in the execution of some such plan as this would be true economy and would bring returns of incalculable value to the city and state. The need of a comprehensive study of all such matters by a broad-minded Civic Improvement Commission has been met by the appointment by Governor Guild of the Commission on Metropolitan Improvements, who will undoubtedly study the whole question broadly and set about the execution not in any wholesale, extravagant manner, but after deliberate study of all desirable plans.

I believe the idea so successfully adopted in many European and some American cities, of acquiring and holding all the lands adjacent to, as well as specifically occupied by, the desired improvements, so that the entire community may benefit by the increased value due to these improvements, is a good one and will result in saving immense sums of money to the community.

We have seen what our neighbors at New York, Philadelphia, Washington, Cleveland and other cities are doing in these respects. Let us not be behindhand. To stand still is to go backward. Our cousin Dietrich Knickerbocker of New York, and our hustling western brothers, are fond of poking fun at the provincialism of our city and our weakness for assuming that Boston is the "Athens of America," and that here is located the real "Hub of the Universe." Now all really good Bostonians know that our claims in these respects are genuine, and we would never admit otherwise to the world, but "just between friends, now," isn't it a fact that while the Hub may be solid and strong, and the rim sound and true, some of the spokes are sadly bent and broken and in need of paint or some other suitable decoration? Let us look to them before it becomes too late; let us straighten and repair them, and, above all, let us see to it that our acropolis on Beacon Hill is treated in a manner worthy of our city, "the Athens of America," which it so nobly crowns.

DISCUSSION.

The President. — I am very glad one of our members has taken up this subject in which we are all interested. The engineers have not considered this question as much as our brothers of the architectural profession, and in all discussions of plans for civic improvement I have noticed that one particular gentleman of that profession has been especially prominent. He has devoted a great deal of time to this matter, and he has kindly accepted my invitation to be here tonight — Mr. C. Howard Walker.

Mr. Walker. — I was not fortunate enough to be here during the early part of Mr. Child's paper, so I did not hear all that he said in regard to foreign cities.

I am not a pessimist in regard to Boston, but I seriously believe and make the statement that there is no city in America that has lost so many admirable opportunities excepting in the single instance of our park system, as has the city of Boston. We have the best opportunities that any city could possibly have. We have the opportunity of the river, of the harbor, of hills that are not too high. From the Common we have treated the park problem on the line of Commonwealth Avenue and the parks beyond, and treated it admirably. Everywhere else we have treated problems as matters of the moment only, not for the future.

Seventeen years ago I worked on a plan for an avenue from

the back of the State House down to the river. Accumulated experience is a very useful thing, and four different times I have seen similar plans suggested. Undoubtedly it must be done at some future time. It is the natural approach from the north of the city.

When I first went into an architect's office twenty-eight years ago there was a little man from Watertown who was making a drawing of the Charles River Basin, which was brought into Mr. Sturgis' office, and I had the good fortune to work upon it, and for fifteen years nothing very much was done in regard to the treatment of this basin. Now the Charles River is being developed, and being developed at a cost so much greater than would have been then incurred that it was certainly not farsighted that the proposition was not taken up at that time.

Now the question has come up about an island in the Charles, and to my surprise and amazement I have had within the last week several residents of the water side of Beacon Street come to me and say they believed that the island would be a good thing. Here is a proposition to make, in the Charles River, land that will divide the river and make that enormous area smaller, and leave on each side of that island a river the size of the Seine in Paris and on one side a river wider than the Thames in London, and still leave an area for a basin at the end of Dartmouth Street four times the size of Alster Basin at Hamburg. The effect of an opportunity to get land upon which to build without paying for it (practically, at least, without its costing the enormous sum that it would cost to buy land), it seems to me would be very great.

In regard to the question of a tunnel between the North and South stations, the Committee of Seventeen of the Boston Society of Architects had, I think, forty-seven schemes for the development of the city of Boston. And those published were only published because they were threshed out from the others and because they did not seem to be too Utopian. But in some of those schemes this tunnel from the North to the South Station was a thing considered necessary and likely to come. The congestion now between those two stations is enormous. An open subway was suggested for teams, and it was found that teamsters were opposed to it. They considered that freight must go through a tunnel in trains or else had to be up on the street. But the tunnel proposition has been brought up again and again. The transit across this city must be underground, and the sooner we recognize that fact the better.

I don't know how much you realize the possible beauty of this city because of the fact that the streets are not straight. Take Cleveland, for instance, where the streets are straight and the city laid out in perfect squares, and there is never a completed vista at the end of the street. We have enormous opportunities for vistas in Boston. I wonder how many of you in going down Beacon Street have been impressed by the fire escape on the corner of the Houghton & Dutton building at the intersection of the streets. I am not saying anything about the building. It is inoffensive enough, if you please, but the fire escape need not be there, and if we had in the least the sense as individuals of making our streets attractive that the Latin races have, that fire escape would be taken off that building within twenty-four hours. It need not be there. It could be placed elsewhere just as well.

We have admirable opportunities at the ends and axes of streets. We are the only city which has a building-law height, and it has saved us a good deal; but we have a very difficult problem to deal with in regard to the large and broad effects. The small holdings are narrow and high. They are bound to be individual. You will find every front different from every other front, and that is a serious problem in making a city beautiful. So I think it is useless to expect that we shall have, without an effort of years, the sort of thing they have in Europe. I do not think we can attain that object without a long struggle.

I have been spoken to again and again, and certainly all of us have been, day after day, in regard to possible improvements, and the suggestions go on record, and some one in the next thirty or fifty or one hundred years who proposes improvements will have the accumulated record of the testimony, and he is going to succeed. The idea of making our streets broad, making well-arranged boulevards, with adequate means of circulation, does not mean a broad street going into a number of smaller ones. It means a continuous avenue from one place to another, having beautiful vistas and buildings worthy of being upon vistas. I wonder how many of you, looking at the photographs, noticed this fact: There was not one that showed a public building which did not have long lines and façades and dignified roofs, all of which tend to increase the dignity of city streets.

I am very much interested and pleased to see how this feeling is growing all over the country. Not only architects, but civil engineers, mechanical engineers, village improvement societies, are all hungry to try to find out how to perfect the heterogeneous

mass of material which has been erected during the last fifty years. We are trying to learn, and our very vitality, individuality and independence are the things in a certain sense which are standing in our way. But now we are beginning to find out the how and the way to do it, and I think that good results will come.

There is one thing I suppose I ought not to say, but I think that of all the miserable curses that ever attacked a city an elevated road is the worst. No matter what it does for transportation, it is deliberately cutting across circulation. It isn't like a simple wall; it isn't considered as a simple wall, and yet every proposition that has come up within the last four or five years in regard to circulation across this city has come across the elevated road. The proposition of getting the custom house with a really fine entrance at the foot of State Street encountered the elevated road. The proposition to get boulevards across the city and have really fine roads could not be acceded to because it cut across the elevated road. I believe as an actual fact that the very men who have advocated the elevated road, if they could live one hundred years from now, would wonder why they ever did it. The congested city has proved to itself time and time again, particularly in Budapest, in Paris, in London, that the best solution of the problem is underground transportation. It is the quickest and it is the best, and if there are elevated roads, they are in the sparsely populated districts, and even there the roads go underground as fast as the districts increase in population.

We cannot compass all these projects. This is an enormous proposition which Mr. Child has presented, a proposition which means a tremendous amount of dealing with large properties that are all entangled, and the taking of which would involve numerous legal questions, and I have been a witness in a very small case in regard to a very small piece of property within the last week, and it has taken about one hundred and fifty times too much time in red tape; and when I begin to look at a proposition like this that has to be dealt with by our brothers of the legal fraternity, I know that generations of them will have been born and have died before we get through with it. Of course we have the right of eminent domain, but there are constitutional questions involved, and it is going to be an extremely difficult matter for a people, for individuals governed as we are, to undertake such large projects until we have had a campaign of education. The thing that pleases me more than anything else is to see the differ-

ent societies taking up this subject, and that they really mean it and are feeling it. Until the mass of the people feels that this is necessary, it is only going to be a lukewarm matter; but the mass of the people is feeling it more and more every day, and I believe that such societies as the Civil Engineers, the Mechanical Engineers, the Society of Architects, the Metropolitan Improvement League and numberless other organizations that are springing up everywhere and taking up this question, will create a sentiment. After all, there never was any real art, architecture, painting or sculpture that was not based on the unanimous sentiment of the people.

The President. — I remember when I was connected with the Boston park system we always had problems we had to struggle to carry out, and I know there was one gentleman who was of great assistance to the commission in articles which he wrote for the press. That gentleman is now the secretary of the Metropolitan Improvements Commission. The gentleman I refer to is Mr. Sylvester Baxter, who is with us to-night. I should be glad to have him say something.

Mr. Baxter. — I have enjoyed more than I can say being with you to-night and listening to this paper, and I am very sorry Mr. Child is not here himself. It is a great pleasure to me to see that the engineers are taking an esthetic interest in the problems that confront us. We have an example of it in our commission in Mr. Desmond FitzGerald, one of your most esteemed members, who has always taken an esthetic interest in public questions. The public owes a great deal to him for what he has been able to accomplish as an engineer in those directions, especially for his work at the Chestnut Hill Reservoir, in embellishing the surroundings and planting trees about that important feature of our water supply, imparting to a great work of utility the character of a beautiful pleasure ground. It is very hopeful that these things are being taken up by the engineers, as well as by the architects, intelligently and farsightedly.

I have been much interested in this problem presented to-night, because it presents a combination of dreams that have come true and of dreams that possibly may not come true, but which still are well worth considering and that, partially at least, may come true in time. You have shown Mr. Eliot's plan here to-night. I happen to have followed that very closely, as I was secretary of the preliminary Metropolitan Park Commission at the time the idea occurred to the author. Later it was presented to the joint board on the improvement of the Charles

River. I remember, and I might disclose some of the history of it here to-night, why this was not made public at the time; why it was not included in the report of the commission. It was because it was thought that it would not do to offend so powerful a corporation as the Boston & Maine by even suggesting the possibility of anything of that kind. But it was included in the life of Charles Eliot written by his father. Some of the most essential parts of it seem destined to come true in the carrying out of plans now under consideration. As to the Charles River Basin improvement, this has come true, and is coming true since Mr. Eliot died, and in even a more beautiful form than perhaps he figured. And certain aspects of this project here seem quite possible; some of the more essential portions of it may possibly come true through the carrying out of the "merger," the combination, in some shape, between the Boston & Maine and the New York, New Haven & Hartford.

Under the "merger," of course, there will be no occasion for a North Station, except a station similar in character to the Back Bay Station. As I understand the plan that the engineers of the New Haven were studying, it is to substitute for the present North Station, somewhere on the north side of the city, perhaps on or about the same site, a station partly or wholly under ground, similar to the Back Bay, and to make the South Station the great central station for the entire city, thereby effecting an economy which will amply pay for all the vast expenditures involved by diminishing by at least 75 per cent. the train movements in and out of the union station as thus organized. So there will be really no terminal station in Boston in the proper sense of the word, because all the trains, as I understand the "merger" proposition — all the trains coming in either way — will pass out through the city and out into the suburbs, and thereby effect that great economy and enormous convenience which the Boston public does not yet begin to appreciate,— the immense economy and convenience which will come from carrying out that plan. It is something which would be worth millions and millions and millions to the city and to Greater Boston in the economy and ease of getting from suburb to suburb and from one part of the metropolis to another, as well as to the most distant parts of the country.

These questions are now all being carefully considered — just beginning to be studied by the Metropolitan Improvements Commission. The basis of these studies, of course, must be the practical considerations involved. Beauty is founded upon

utility, and at the foundation of Boston are industry, commerce, trade. Hence, starting from these things, these studies must proceed and must be developed upon those bases. Therefore, the commission is beginning with the question of docks and terminals — the industrial aspects, such as accommodation of local conditions to manufacturing enterprises in various parts of the metropolitan district, and other utilitarian questions of that sort. And from a clear understanding of those things the elements of transit must be evolved, followed by the plan which will be useful and also beautiful because it is useful. That is what is hoped for. It has been very interesting to be able to perceive the sentiment as developed at the hearings that have thus far been held. There have been three hearings so far, private hearings, at which were representatives of commercial interests, of the great steamship companies running from Boston, members of the Chamber of Commerce who are intimately acquainted with the character of the grain trade and the transportation interests. It is very hopeful to see that among all those the sentiment is unanimous that there is no occasion whatever for any pessimistic talk about the future of Boston. Boston has the greatest of opportunities, and if these are properly taken advantage of, things are bound to come right. What is chiefly needed is to take hold of these problems with confidence and with a sense of unity, of solidarity.

The representatives of the foreign steamship interests tell us that our docks are obsolete; that the present docks of Boston are absolutely inadequate to the needs of modern commerce. For instance, the resident manager of the great International Mercantile Marine Company says that it was proposed very recently to put on to the Boston service the great steamship, the *Celtic*, one of the biggest steamers on that line, but their agent here said it was absolutely impracticable owing to the character of the docks. They couldn't possibly handle the business. And so Boston must have new docks in order to accommodate her growing commerce. These are some of the questions for the next year. Their practical development will be of the greatest interest, and I feel confident that the commission will welcome the coöperation of the engineers as they will also that of the architects.

[NOTE.— Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by March 16, 1908, for publication in a subsequent number of the JOURNAL.]

PURIFICATION OF BOSTON SEWAGE: EXPERIMENTAL RESULTS AND PRACTICAL POSSIBILITIES.

C.-E. A. Winslow and Earle B. Phelps, Members of the Boston Society of Civil Engineers.

[Read before the Sanitary Section of the Society, November 15, 1907.]

The Sanitary Research Laboratory and Sewage Experiment Station of the Massachusetts Institute of Technology was founded in 1902 by an anonymous donor for the purpose of making experiments upon improved methods of sewage disposal. A large part of the work of the staff has been devoted to the study of the more purely scientific problems — chemical, bacteriological and hydraulic — which underlie the practice of sewage analysis and sewage purification. We have carried on, however, along with these theoretical investigations, an experimental study of the immediate local problem of sewage disposal as it is certain some day to confront the city of Boston.

The sewage of the Metropolitan district of Boston at the present time is discharged into the waters of the harbor at three different points.

The main outfall of the sewer of the north district carries some 50 000 000 gallons daily and discharges continuously off Deer Island. The sewage from the high level district passes out to Peddock's Island, near the southeastern limit of the harbor, and this amounts to about 20 000 000 gallons. The main outfall of the South Metropolitan district is at Moon Island, and here the sewage is stored in masonry tanks and discharged only on the turn of the tide. The daily flow in this sewer is in the neighborhood of 100 000 000 gallons.

The Massachusetts State Board of Health investigated the condition of Boston harbor in 1905 and found no serious damage from this method of disposal. The town of Wellesley has, however, recently been refused admittance to the Metropolitan system from fear of overtaxing the purifying power of the harbor (Report of Committee on Sewerage Commission, Wellesley, 1907). It can scarcely be doubted that the progressive increase of population within the drainage district itself will ultimately bring the problem of sewage purification to the fore. The present agitation in regard to the pollution of New York harbor under some-

what similar conditions is an indication of what must some day be expected in Boston.

Under these circumstances it is important to form some general idea beforehand as to what a proper purification of Boston sewage will involve; and our investigations have now reached a point at which this can approximately be determined. It should be understood that neither state nor municipal authorities are responsible for our conclusions. The investigations here reported proceed wholly from the Sewage Experiment Station of the Institute of Technology, and they deal with a coming problem rather than a present one. It is hoped, however, that they may yield data of importance in determining the feasibility of a disposal project when the time for it shall come, and offer some guidance as to its probable final form. Furthermore, as this is the first investigation to be completed of disposal of the sewage of a large American seaboard city, it is hoped that the results will have some interest for other cities similarly situated.*

This study has now been carried on for four years. The first two years were spent in a preliminary examination of various processes of sewage treatment as applied to this particular sewage, carried out in a number of small cypress tanks. These preliminary studies showed that it was feasible to treat the sewage on sand beds or on contact beds. The first process required a large area of land. The second process, the contact bed, yielded an effluent of fair quality, only when the sewage was passed through two successive beds; and again a large area was necessary. It was found possible to treat the sewage by the double contact process at a net rate of about 700 000 gallons per acre per day.

In these preliminary experiments it appeared that the trickling beds, or the percolating beds, as they are more commonly called in England, would furnish by far the most satisfactory solution of the problem. We did not feel justified in attaching great importance, however, to the results of the first two years' work on trickling beds. Although the small experimental filters yielded data of comparative value, particularly in regard to contact treatment, the success of the sprinkling bed depends so largely on the manner of design, and is so much affected by weather conditions, that it seemed necessary to have experiments on a larger scale and out-of-doors, upon which to base any final conclusions.

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* The full details of the experiments will be published in the *Technology Quarterly* for December, 1907.

Two years ago, therefore, two trickling beds were built, which were then the largest of their kind in operation in this country. Sewage from the main sewer of the South Metropolitan district was pumped directly into a tank which served for dosing the rest of the plant. Nothing was removed from the sewage before treatment except such screenings as would separate in passage through a section of 20-in. pipe set at right angles to the suction main, so as to form a grit chamber with a screen of bars half an inch apart. All the fine material in the sewage went into our distribution tank. From that tank a small portion wasted over a weir maintaining a constant head, and from the other end of the distribution tank sewage passed directly to one of the trickling filters. From the side of the distribution tank sewage passed through another pipe to the septic tanks, and from the last of five successive septic tanks the septic effluent passed out into the other one of the trickling beds. The septic tanks were, as has been said, five in number, built of cypress, 6 by 4 by 3 ft., and giving a storage period of twelve hours.

The trickling beds themselves were two in number. Each one was 8 ft. deep, and each had an area of 100 sq. ft. These beds were filled with 1½ to 2-inch crushed stone resting on 18 inches of large material. The sewage was at first distributed on the beds by a new method which has been developed at the station and which has some advantages — a method which we have called the gravity distribution method. The sewage flowed out through wooden troughs and dropped through the bottom of these troughs, through half-inch nozzles, on to concave metal disks and splashed up from the disks in fine spray.

During the first year of operation there were four of these splashing disks on each filter, and as the filters were operated at the rate of about 2 000 000 gallons per acre per day, or 5 000 gallons per day upon each of the two experimental filters, the flow through each nozzle was not very great and we did not obtain very satisfactory results in the way of distribution.

After a year's operation the distribution system was changed. On one filter — the one that took the crude sewage — a single splashing disk instead of four was substituted, the new disk taking four times the flow of each of the earlier ones. This worked very satisfactorily. On the other filter one of the Columbus pressure sprinkler nozzles was installed, but as this nozzle gave too high a discharge for our filter — a discharge in excess of 2 000 000 gallons per acre per day — we used an intermittent siphon tank to dose it. Half the sewage therefor flowed from the distribu-

tion tank directly on to one filter, being distributed by a gravity distribution system. The other half flowed through the septic tanks and from the last septic tank by an automatic siphon and the Columbus sprinkler on to the other bed. From the two filters the effluents were conducted through two separate pipes to sedimentation tanks, simple, conical tanks giving the effluent from the filter a two-hour storage.

Samples of sewage and of all effluents were taken every three hours, the samples being chloroformed as soon as they were taken and mixed and analyzed once a week so as to be thoroughly representative. In the study of these samples the ordinary chemical and bacteriological tests were made. Even greater importance, however, was attributed to tests of putrescibility. The object of sewage treatment is to obtain a stable effluent, and in dealing with the newer processes, the trickling bed and the contact bed, one finds that ordinary chemical methods of judging effluents are entirely inadequate. You may have one effluent entirely stable and of such a character as to be discharged into a stream without danger, and you may have another which is putrescible and which would cause a nuisance, and the analyses of these two effluents may be practically the same. Chemical methods are not sufficiently delicate to detect the difference between a good and a bad effluent. Fortunately there has recently been devised — it comes to us from Berlin — a simple method of measuring this elusive quality of putrescibility. This test is made by adding to a small sample of sewage a few drops of methylene blue solution and then bottling it up. The methylene blue is readily attacked by bacteria, but not so readily as oxygen or oxygen-containing compounds like nitrates and nitrites. When a sample of sewage is bottled up in this way the bacteria in the effluent first use up the dissolved oxygen, then the oxygen in nitrates and nitrites. When all this easily available oyxgen has been used up, the blue color rapidly disappears. The time during which the sample remains blue when bottled up in this way is a delicate measure of its stability, of the balance between oxygen and oxidizable matter. If the oxygen is in excess of the oxidizable matter, the methylene blue will retain its color. If the oxidizable matter is in excess, the oxygen will be used up and the methylene blue reduced and decolorized.

The first point to be considered in planning for a purification plant is the character of the sewage with which it will have to deal. We found that Boston sewage is an average domestic

sewage. It is weaker than the sewage of many small Massachusetts cities where there is a large proportion of house sewage. On the other hand, it is comparable with the sewage of the larger cities. Its organic content is slightly greater than that of the sewage of Columbus, Ohio, where Mr. Fuller and Mr. Johnson made their very careful study two years ago. For example, the oxygen-consumed value is 56 for Boston against 57 for Columbus, the free ammonia value is 13.9 against 11, and the Kjeldahl nitrogen figure is 9.1 against 9. Columbus sewage contains only 79 parts of volatile suspended solids, while Boston sewage has 91. On the other hand, Columbus sewage has 130 parts of fixed suspended solids against 44 parts for Boston.

The complete septic tank system consisted of five tanks. We tried, during the first year, the use of three tanks only, giving a storage period of seven hours. Later we added to the series the two other tanks, giving a storage capacity of 12 hours, but the change was not accompanied by any improvement in the results. Apparently the seven-hour period was as satisfactory as the longer one. The five small tanks were baffled so that their net effect was about that of a tank 30 ft. long, 4 ft. wide and 3 ft. deep.

Comparing analyses of the septic effluent with those of the crude sewage, it appears that the tank system removed 40 per cent. of the total suspended solids and 69 per cent. of the volatile suspended solids. There was a 29 per cent. decrease in total organic nitrogen and a 26 per cent. decrease in the organic nitrogen in solution, while the free ammonia increased by 20 per cent. The oxygen-consumed values were about the same in the effluent as in the crude sewage. The removal of organic matter from season to season did not vary materially as a whole, but soluble organic nitrogen was more reduced during the second and the third quarters of the year than at other times, whereas at the same seasons the production of ammonia was greater. These phenomena are both, of course, correlated with the increased bacterial growth in warm weather which has been noticed by Kinnicutt and Eddy at Worcester, and by Clark at Lawrence in connection with their studies of gas production in closed septic tanks. This point is of great importance in considering the efficiency of the septic tank under varying climatic conditions. Fowler has pointed out that in India septic tanks work perfectly, while in Russia they are unsatisfactory. In removing suspended solids the septic tank was least efficient just at the time of its greatest biological activity, when the bacteria were growing most rapidly

and there was the greatest stirring up of the tank and the most sludge carried over.

We studied the accumulation of sludge in the tanks rather carefully at three periods of the investigation, stirring up all the tanks and analyzing samples of the mixed tank contents, getting in that way the total amount of organic and inorganic matter stored. We measured 4 inches of sludge at the end of 12 months of operation and nearly 12 inches at the end of 20 months, so that the sludging up was proceeding at an appreciable rate. We found, however, by the analyses, in comparison with the analyses of inflowing sewage and of the effluent, that the tanks had done excellent work as far as the liquefying of organic matter went. For example, of the volatile suspended solids in the sewage, 69 per cent. went off in the effluent and 31 per cent. stayed in the tank. Of that 31 per cent. only 6 per cent. was stored, while 25 per cent. of the original amount present, four fifths of that stored, had been decomposed. Almost exactly the same proportion held for the organic nitrogen. Of the 29 per cent. which was removed by the tank, only 4 per cent. remained, and 25 per cent. of the total, or four fifths of that which was deposited in the tank, was liquefied.

On the other hand, it was interesting to notice that there was a slight increase in the fixed suspended solids, about 3 per cent. of the total amount in the sewage, due perhaps, to the precipitation of sulphides formed from the sulphates in the sea water. Our sewage resembles that of some of the western cities where they have hard water, since it contains a considerable amount of sulphate coming from the sea water which enters the sewers.

On the whole, the septic tanks did good work both in the removal of suspended matter and in its decomposition. Nevertheless, after two years, an appreciable amount of sludging had taken place, due largely to the accumulation of fixed solids.

In the operation of the trickling filters, some slight trouble was experienced during the first year. In the summer of 1906 a little clogging occurred and we found it necessary to work over the stone on the surface of the beds, though none of it was removed. But after the new sprinklers were put in place, the Columbus nozzle on one side and the single gravity sprinkling disk on the other, the filters worked admirably.

With regard to suspended solids, the amount discharged by the filters was found to be very close to that which was applied. On the crude sewage side it was slightly in excess, 138 parts per million against 135 parts per million in the applied

sewage. On the septic side the increase was greater, 86 parts per million going in and 96 parts per million coming out. The seasonal curve of suspended solids is very interesting. During three fourths of the years the filters diminished the suspended solids, but in the spring the effluent showed a great increase, the amount rising to twice or thrice the value for the applied sewage. This happened in both years in the same way with perfect regularity. It is interesting as showing that the trickling bed is a biological organism which is delicately adjusted. It is able to assimilate and store a certain amount of suspended solids and beyond that amount it begins to discharge. We found that the curve followed not the rainfall but the temperature. As the temperature went up in the spring, and as the bacteria began to multiply in the trickling bed, the load of solid matter on the stones increased until it reached the maximum thickness that could be sustained and then broke off of its own weight; the whole mass that had been accumulated during the preceding nine months came off in three months of the spring. But it came off in a stable condition and without danger to the effluent. The practical importance of this result lies in the strong hope which it furnishes of the permanence of the trickling bed. If the trickling bed is able to free itself of suspended solids in this way without damage to the effluent, there is no reason to anticipate permanent clogging of such beds when properly operated.

With regard to chemical constituents, the trickling bed showed, as usual, a considerable purification. For example, the total organic nitrogen was reduced by 22 per cent. on the crude sewage side and by 23 per cent. on the septic side. The organic nitrogen in solution was reduced by 47 and 44 per cent., and the free ammonia by 25 and 28 per cent., respectively. The oxygen consumed in solution decreased by 42 and 43 per cent. These figures, of course, would not indicate satisfactory purification if they told the whole story; judging from chemical results alone, we should say the beds were not doing good work. We should say the same thing judging any trickling bed or any contact bed by chemical analyses alone.

Five to six parts per million of nitrates were found in each case, and the effluents contained an ample supply of dissolved oxygen. The real test of a trickling effluent, however, is its stability, and this was measured by the methylene blue method. During the first year, results were not always satisfactory. Sometimes the samples would remain colored for two weeks, which was the maximum period for which they were kept. Some-

times they would lose their color in from two to four days. Results varied at different times and in the two filters. But after the installation of the new distribution system the results were very good indeed. From December 15, 1906, to June 28, 1907, 156 samples of each effluent were examined by the methylene blue test. On the crude sewage side, 127 samples out of 156 were stable for 14 days, 19 more were stable for over 4 days and 10 only became decolorized in 4 days or less at 20 degrees. The effluent of Filter B showed 129 samples out of 156 stable for 14 days, 16 more stable for more than 4 days and 11 decolorized in 4 days or less. In other words, 93 per cent. of both effluents were of sufficiently good quality to retain free oxygen for over 4 days, — a severe test, — and the results therefor indicate an effluent of satisfactory quality. The two beds gave results, as will be seen by the methylene blue figures, of approximately the same character. The effluent from the bed receiving the crude sewage was as good as the effluent from the bed receiving the septic effluent. This was one of the most important practical results of the experiments. There appeared to be no advantage in the preliminary septic treatment as far as final stability is concerned. Of course, the effluent from the bed receiving the septic effluent had less suspended matter than that from the bed receiving the crude sewage, but the purification was equally good and the stability of the effluent was equally good with the crude sewage.

At the close of 20 months' experimentation, the beds were taken to pieces and examined carefully. There was found on the crude sewage side a slight deposit about one foot down under the four old sprinklers. The rest of the bed was clean and the septic side was clean. The stone was in condition to be put in place again without washing. It is interesting to notice, however, that on the septic side there was a deposit half an inch thick all over the bottom of the filter, largely made up of sulphides, produced in the septic tank but not deposited there.

The effluents, of course, were turbid, containing a great deal of suspended matter, and under certain conditions this might be objectionable. In the hope of effecting an improvement in that respect we used our sedimentation tanks and found that by two hours' sedimentation it was possible to remove one half of the suspended matter present, greatly improving the appearance of the effluents. The price which must be paid for this additional improvement in appearance, however, is a somewhat serious one. Sedimentation means the disposal of sludge from sedimentation

tanks, and it was found that this amounted to between two and three cubic yards per million gallons of sewage treated. Although the effluent that comes from the filters is stable, the sludge alone is not always so; stability means a relation between oxygen and oxidizable matter, and if you separate the oxidizable matter from the oxygen, conditions are altered. It is therefore safer to discharge the sludge along with the effluent when it is possible to do so.

It seems, then, that the trickling bed will furnish a satisfactory solution of the problem of organic purification. But the problem of sewage purification is twofold. First, there is the question of nuisance; and, second, the question of getting rid of disease germs. For bacterial removal the rapid processes of sewage treatment are entirely inadequate. Comparing the effluent of Filter B with the crude sewage, it is apparent that the septic tank and the trickling bed combined reduced the total number of bacteria from 1 200 000 to 180 000, a diminution of 85 per cent., not one which could be considered satisfactory. Results regarding the removal of bacillus coli showed during the summer time even poorer results, the removal being under 50 per cent. by the septic tank and the trickling bed combined.

These results are as good as can be expected, for filters of this type cannot be relied upon to secure bacterial purification. For these reasons the Baltimore experts suggested secondary filtration through sand in order to avoid possible danger to the shellfish industry of Chesapeake Bay. The Board of Advisory Engineers of Baltimore estimated the cost of works for the complete treatment of 75 000 000 gallons of sewage per day at $3 283 250, of which sum $1 040 750, or more than 31 per cent., was for supplementary treatment on sand filters. The annual cost of operation was estimated at $115 500, of which $55 000, or 48 per cent., was for supplementary treatment. So that the treatment of the effluent from trickling beds so as to remove bacteria by the sand process is a costly procedure.

Fortunately, we have now a cheaper and equally efficient method of attaining the same end in the process of chemical disinfection. The application of chemicals as a method of sewage purification, that is, as a method for the removal of organic matter, has been pretty well discredited in most instances. But this problem is an entirely different one. In the old days the attempt was made to remove organic matter by the use of chemicals. Now, having oxidized the organic matter by the trickling bed, we may use chemicals for removing bacteria.

After the organic purification is attained, bacterial purification may be effected by chemical methods.

The first work that attracted attention to this point was that of Rideal in England, who, in a series of experiments at Guilford, showed the possibility of the treatment of sewage and sewage effluents with chloride of lime so as to secure a very large percentage of bacterial removal. Notice was first called to the practicability of the method in this country by Phelps and Carpenter about a year ago. Since that time the process has attracted much attention. It was found by Phelps and Carpenter that neither the addition of large amounts of bleaching powder up to 100 parts of available chlorine per million nor the storage of the effluent for periods of time up to 20 hours would remove all the bacteria. On the other hand, a comparatively low concentration of chlorine applied for 2 hours gave a very large reduction, the residual organisms being almost entirely saprophytic spore formers. Sterilization is, therefore, not feasible, but disinfection is.

It is important to distinguish between complete sterilization and a reasonable percentage purification, such as is attained in water filtration. Neglect of this discrimination has led to the use of excessive quantities of lime in certain recent German experiments. The character of the sewage, too, will materially affect the results. Good efficiency has been reported in recent experiments on the disinfection of septic effluent at Bengal, India. On the other hand, Kellerman, Pratt and Kimberley, in Ohio, found considerable quantities of lime necessary for treatment of certain effluents there.

In August, 1906, routine disinfection of the effluent from Filter A, taking the crude sewage, was begun, chloride of lime being added from a small orifice box as it flowed into the sedimentation tank at a rate of about five parts of available chlorine per million. This application gave very good results. It showed 99.99 per cent. purification on total bacteria and bacillus coli, which results are all that can be expected from any practical method.

The general conclusions from this work may be summarized as follows:

1. *Trickling Beds.* — The main result of this investigation has been to show the feasibility of treating Boston sewage on trickling beds so as to secure organic stability. In the experiments conducted, the filters were operated at a rate of about two million gallons per acre per day, which would call for 50 acres of

stone beds for the treatment of the sewage now discharged at Moon Island. A comparison with the problem of constructing 133 acres of contact beds, or 1 000 acres of sand beds, which would be necessary for other processes, indicates clearly that for this city the trickling bed offers the most practical method of treatment.

We have found that, with good distribution, a trickling bed 8 feet deep will operate successfully at all seasons, under local weather conditions. It removes about half the soluble organic matter, yielding an effluent which is somewhat turbid, but stable and well oxygenated. The organic matter present has been so worked over and purified by the bacteria in the filter as to be non-putrescible. Judged by the methylene blue reduction-test, 90 per cent. of the samples of the effluent are of such stability as to undergo no putrefactive change when kept closed up from the air for 4 days. Under ordinary conditions of discharge into open water such an effluent would be entirely unobjectionable.

The proper distribution on trickling beds can be attained either by the use of fixed sprinkler heads of the Columbus type, so arranged as to discharge intermittently at frequent intervals, or by the use of the splashing gravity distributors designed at the experiment station for this purpose.

With good distribution the trickling beds show no appreciable tendency to clog. During the greater part of the year, solid matter accumulates on the surface of the stones throughout the bed, but when this storage reaches a certain point, usually in the early spring, the solids break away and come off in the effluent in a stable condition. In a period covering two years the total amount of solid matter coming off balanced that going on. The filtering material at the end of the experiments was in excellent condition and showed no storage of nitrogen.

Our results point strongly to the advantage of operating trickling beds under conditions as uniform as possible. Resting periods proved distinctly detrimental to the work of the beds, and constant operation is to be recommended rather than any process which involves alternate working and resting periods.

2. *Septic Tanks.* — It appears from our experiments that Boston sewage may be treated in the septic tank with excellent results and that a period of 7 hours is a sufficiently long one. Thus operated, an open tank will remove 40 per cent. of the total suspended solids and 60 per cent. of the fixed suspended solids; its effluent shows a decrease of about 25 per cent. in organic nitrogen in solution and a corresponding increase in free ammonia.

The septic action on the stored solids is an active one, four fifths of the organic solids deposited disappearing in solution or as gas. Fixed solids gradually accumulate so as to render it probable that tanks would require cleaning about once in two years.

On the whole, however, our experiments indicate that the septic tank need not be used at all in the treatment of Boston sewage. Since November, 1906, when the distribution system was put in order, crude sewage has been treated on one of our trickling beds with perfect success. On the whole, the effluent from this filter was less frequently putrescible than that from the bed which received septic effluent. Furthermore, the filter taking septic effluent showed a deposit on its floor, due to secondary reducing changes, which was absent from the crude sewage bed. Furthermore, the absence of the odors produced by spraying septic sewage is an advantage of considerable moment in favor of the process of treating fresh sewage. Combined with the saving of the cost of tanks (in the neighborhood of $250 000) these arguments seem to indicate the treatment of crude sewage directly on trickling filters as most desirable. Modern devices for insuring a thorough preliminary screening should, however, be installed.

3. *Sedimentation of Trickling Effluents.* — The suspended solids which appear in the trickling effluent, though inoffensive, are unsightly and in many locations might require removal. By a sedimentation of two hours we have found it possible to remove about half the suspended solids. This clarification was accompanied by an improvement in stability.

In the case of Boston the currents of the harbor would be amply competent to care for the solid matter discharged if that matter were of an inoffensive and non-putrescible nature. Experience with the system at present in use has indicated this quite clearly. For a comparatively slight improvement in stability it does not appear to us justifiable to go to the expense of installing secondary sedimentation tanks. The sludge accumulating in such tanks would amount to 2 or 3 cubic yards per million gallons of effluent, a serious problem in itself. We are, therefore, of the opinion that the effluent from the trickling beds may best be discharged directly into the harbor as it comes from the beds. A stable effluent under such conditions could cause no nuisance, and if a submerged discharge were provided, its presence would scarcely be detected.

4. *Disinfection of Trickling Effluent.* — The problem of bacterial purification still remains to be considered, since the

trickling bed produces organic stability without destroying pathogenic bacteria. In the case of Boston harbor, with its large contiguous population, its bathers and its shellfish industry, this aspect is an important one. The experiments carried out during the last two years have made it clear that the effluents from trickling beds may be so purified bacterially by disinfection with chlorid of lime as to be of much better quality than the present streams entering Boston harbor. This bacterial purification requires about five parts of available chlorin per million and the cost of treatment would be within moderate limits.

The process of disinfection with chlorin can be applied to crude sewage as well as to trickling effluent, although experiments carried out at the Station indicate that about double the amount of chlorin is needed on account of the reducing action of the organic matter in the sewage. Pending the construction of a trickling filter plant for the treatment of the organic matter in Boston sewage, it might well be purified bacterially by this process at the present Moon Island outfall.

5. *General Plan for the Treatment of the Sewage of the South Metropolitan District.* — The sewage outfall of the South Metropolitan District at Moon Island is the one which threatens most seriously to menace the purity of Boston harbor, and it is this sewage which will certainly first require some different method of treatment. We have, therefore, considered, in a general way, the practical problem of dealing with this sewage in the light of the results of our experiments.

The most convenient location for a trickling filter area would be at the Calf Pasture in Dorchester, near the present pumping station. This is objectionable, however, on account of its proximity to the thickly settled portion of Dorchester. Furthermore, the necessity for excavating about ten feet of mud and refilling in its place would greatly increase the cost of construction at this point. The same objections apply to certain waste areas on the Neponset marshes which suggested themselves as possibly available. The headland of Squantum would offer an ideal opportunity for building trickling beds, but the difficulties of obtaining land in another town militate against the use of this site.

The southern portion of Thompson's Island would furnish a location free from all the objections to which the other sites are open. On an embankment 1 500 ft. long the sewage could be carried from Squantum across to the island, the effluent flowing

back along the same embankment to the existing outfall sewer. The pumping station at Dorchester, and the tanks and outlet at Moon Island, could thus be used without substantial changes. We have made preliminary estimates of the cost of building 50 acres of trickling beds, 8 feet deep, and equipped with the gravity distribution system, and are of the opinion that the cost, including the embankment with its two sewers, an efficient grit chamber, a reasonable purchase price for the necessary land, grading, stone filling brought to the island by water, concrete construction and sprinklers, would be in the neighborhood of \$1 800 000.*

If this capital sum were borrowed at 5 per cent. on a twenty-five year loan, the annual expense for interest and sinking fund would be \$126 800 a year, paying off the entire cost in the twenty-five year period. As a matter of fact, we see no reason to suppose that at the end of this time the plant would not be good for another twenty-five years without substantial reconstruction. The cost of operation, including extra pumping and supervision of screens and filters, would amount to \$70 000 a year, bringing the total cost to about \$200 000 a year, or \$5.50 per million gallons of sewage treated.

The effluent from the trickling beds, wherever situated, could be further bacterially purified by disinfection with chlorid of lime at a cost of approximately \$1.50 per million gallons, or \$55 000 annually.

Pending the construction of filters for the removal of putrescible organic matter from Boston sewage, if it should seem desirable to secure bacterial purification, this may be effected by direct treatment of the crude sewage with chlorid of lime, which could probably be done for \$3.00 per million gallons, or \$110 000 annually.

Experiments are now in progress at the Experiment Station to test the practicability of higher rates of filtration and shallower beds than those used in the experiments on which these calculations are based, as well as on the treatment of sewage and effluents by electrolytically produced chlorin. It is hoped that these experiments may lead to a material reduction in the estimated cost of the purification processes. It seems clear, however, that the combination of trickling filters and chemical disinfection will solve the Boston sewage problem satisfactorily; and in the light of present knowledge these two methods are the most efficient and economical available for the purpose.

* The authors desire to express their thanks to Mr. W. S. Johnson for assistance and advice in the preparation of these preliminary estimates.

DISCUSSION.

Mr. X. H. Goodnough. — I have had no opportunity to see this paper or to learn definitely what its tenor was before the meeting, so that I am not prepared to discuss it very fully. I did get some information as to what its conclusions might be from a statement in the Boston *Herald* this morning, outlining the paper in a general way, and there are a few things which I would like to say with regard to questions discussed therein.

In the first place, as to the experiments themselves, they add materially, of course, to our information as to methods of sewage disposal. And anything that adds to that information is a great help at the present time. The portion of this paper that I wish to consider, however, is the practical side.

The sewage of the city of Boston has now been discharged at Moon Island for a period of nearly twenty-four years. The quantity constantly increased in the first few years, — that is, beginning in 1884, it constantly increased for a few years, first by the growth of the city; then by the addition of the sewage of the Charles River Valley, in 1892; and later by that of the Neponset River Valley, about 1897 or 1898.

In 1904, on the other hand, by the completion of the high level sewer, the diversion of sewage from Moon Island to the new outlet at Nut Island was begun, and during the past year 33 000 000 gallons have been discharged daily at the latter outlet. The quantity ordinarily discharged at Moon Island at the present time is not measured and we have no means of knowing how much it is, but it probably averages less than 100 000 000 gallons per day.

A very thorough examination of the waters of the harbor made two years ago showed that, except in the immediate neighborhood of the main sewer outlets, the upper portion of the harbor was more seriously polluted than any other, that is, the portion about Fort Independence or Fort Winthrop. But even in this region the harbor waters are not objectionable to sight or smell.

The chief difficulty resulting from the discharge of sewage into Boston harbor at the present time is the effect of the sewage upon shellfish which have formerly been collected in considerable numbers from the flats in various parts of the harbor and the adjacent tidal estuaries. This pollution is caused, chiefly, not by the discharge of sewage from the outlet at Moon Island or any of the other main sewer outlets in Boston harbor, but by the discharge of sewage from minor outlets along the shores of the harbor and its tributaries, in the neighborhood of areas from which the shellfish are taken.

The most seriously objectionable conditions resulting from the pollution of local waters by sewage now existing are found in the valley of the Charles River and Stony Brook above the proposed new dam between Boston and Cambridge. A careful examination of Stony Brook in 1906 showed that the quantity of sewage being discharged into that stream from the sewers of the city of Boston had increased greatly as compared with the amount found there in 1902, and in its report to the legislature in January of the present year the State Board of Health makes the following statement and recommendation:

"The information available to the board shows that the sewerage and drainage of these districts [the Stony Brook and Charles River drainage areas] is inadequate and unsystematic, and, unless a practicable and adequate plan for the collection and proper disposal of the sewage, rain water and other drainage of these districts shall be devised and intelligently carried out in the future, objectionable conditions resulting from the present faulty sewerage and drainage systems will inevitably grow worse.

"The board would recommend that an investigation be made and plans prepared for the adequate sewerage and drainage of the Stony Brook Valley and the districts adjacent to the Charles River in the city of Boston."

The legislature subsequently passed an act which provides that during the next five years the city of Boston shall expend a sum amounting to somewhat more than $600 000 yearly in separating the sewage from the storm water in the valley of Stony Brook and the districts tributary to the Charles River, for the purpose of preventing the pollution of those waters.

The only practicable way of preventing the gross pollution of the Stony Brook channels and the Charles River into which they flow is the separation of the sewage from the storm water throughout those districts, and this is the most pressing of the improvements that are necessary in the sewerage of the city of Boston at the present time. The rebuilding of the sewerage system in the valley of Stony Brook and the Charles River, with the carrying out of other necessary sewerage works, will absorb all the funds which the city, in its present financial condition, is likely to be able to spare for several years to come. But the construction of these works is of far more pressing importance in the improvement of sanitary conditions in the Metropolitan district than any question of further treatment of the sewage discharged at Moon Island or at any of the other outlets in Boston harbor.

In other words, the problem is not at the outlet at Moon Island; it is in the inner harbor and in waters adjacent to the

inner harbor. The examinations of two years ago, as I have said, showed that the worst conditions were found in the inner harbor. The question of the filling up of the harbor, to which reference has been made by a witness before a commission at a hearing in Boston the other day, and in various newspapers, was very thoroughly settled in 1901 and 1902 by the investigation and report on the construction of the dam in Charles River. In the course of those investigations careful measurements were made of currents in Boston harbor, and soundings were made. Furthermore, all the available soundings made in the various years, beginning sixty or seventy years ago and coming down to the present time, were compared, and no definite evidence was found of shoaling anywhere in the harbor except in the inner harbor, where it was due to various causes, much of it to shipping.

The objectionable effect upon the harbor of the sewage discharged at Moon Island at present is less than the effect of that discharged at other points. The sewers in the cities of Boston, Cambridge, Somerville and Chelsea are constructed chiefly upon the combined plan and are designed to remove both the sewage and the storm water due to rain and melting snow. The intercepting sewers which convey this sewage to the three main harbor outlets at Moon Island, Deer Island and Peddock's Island are designed to take only the dry weather flow of the sewers of those cities, together with a small quantity of rainfall, estimated, in the case of the Boston sewers, to amount to about one quarter of an inch per day.

At times of rain, or when snow is melting rapidly, a part, and sometimes the greater part, of the mingled sewage and storm water of these cities is discharged through temporary overflow outlets into the waters of Boston harbor and its tributaries. Not only is a part of the mingled sewage and storm water allowed to overflow into the harbor at times of storm, but in the case of the city of Boston special effort is made to provide for the drainage of certain low sections of the city and prevent the flooding of streets and the basements of buildings by allowing a free connection through which the storm water may enter the intercepting sewers from such districts at times of storm to the exclusion of mingled sewage and storm water from other districts.

It thus happens that sometimes for days together large quantities of sewage are discharged through overflow outlets directly into the harbor or its tributaries. When it is realized that the total number of such overflow outlets is, at the present

time, more than two hundred, the impracticability of any plan of disinfecting the sewage discharged into the harbor will be readily understood.

The statement has been made that there is a limit to the quantity of sewage that Boston harbor can receive, and that in consequence the sewage of the town of Wellesley has been excluded. The real fact of the case is that there must be some limit to the quantity of sewage discharged into Boston harbor, though that limit has not been reached. There have been schemes in the legislature for discharging the sewage even of Worcester into Boston harbor. In 1900, by direction of the legislature, the State Board of Health, in an investigation relating to a proposed high level sewer, suggested a limit beyond which it was unnecessary to take sewage into Boston harbor, and Wellesley is beyond that limit. The town of Wellesley can dispose of its sewage at less expense within its own territory than it can in connection with the Metropolitan system. Moreover, the expense to the Metropolitan District of including Wellesley in the Metropolitan sewerage system would be greater than Wellesley's contribution to the support of that system under existing conditions.

It is likely, from present indications, to be many years before treatment of the sewage discharged into Boston harbor from the main outlets of sewers there will become a question for serious consideration.

PROF. WILLIAM T. SEDGWICK.* — I am glad to be present this evening and to share with Professors Winslow and Phelps great pleasure at the interest displayed in this work in which we have all been so much interested ourselves. I may say just a word or two about the general scheme of the sewage station, particularly as connected with an educational institution.

We were given $5 000 a year, several years ago, by an anonymous donor who had been moved by a belief that the harbor was being very seriously polluted and who was persuaded that more ought to be done than had yet been done toward the treatment of the sewage of large cities. The donor had no very definite ideas as to procedure, but believed that an educational institution like the Institute of Technology ought to be able to take up a problem of this kind and contribute to its solution.

It was pointed out by us to the donor that the State Board

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* Director Sanitary Research Laboratory and Sewage Experimental Station, and Profesor of Biology, Massachusetts Institute of Technology, Boston.

of Health had already done a large amount of able and pioneer work along these lines, but of course no educational establishment has the right to refuse a gift of $5 000 a year for experimentation in science if it can help it, so we set to work to make as good use as we could of this moderate sum. I think you will agree with me that we have already learned and done something.

The opinion that Boston harbor is going to the bad has lately found expression in newspaper statements, and through a witness before a recent commisson hearing, to the effect that it is filling up with great rapidity; so much so in fact that newspapers outside of Boston have touched upon the subject and have wondered that so intelligent a city as Boston is supposed to be, in a state as advanced in sanitary measures as Massachusetts has always been, should be content to allow this thing to go on. Now, of course, the real explanation is, as it was in the old story, — the boy lied. That is to say, the harbor is not sludging up in the way in which it was said to be filling, because Mr. Goodnough's very careful examination of 1900 and 1905 did not disclose anything of the kind. Besides, the federal authorities are constantly observing conditions in the harbor with jealous eyes lest sludging up should be impeding navigation, while our own state Harbor and Land Commissioners are expressly charged by statute to have a care that no unauthorized encroachments are allowed to interfere with the natural conditions of our harbors. And, as you know, we have a good Harbor and Land Commission, with a competent engineer in charge. We may, therefore, dismiss at once any fear that the harbor is rapidly filling up with material settled out from sewage. There is a pretty good circulation in the harbor which takes out much of whatever accumulates, more particularly during heavy storms. But at the same time we cannot look with equanimity upon the increasing discharge of sewage, as such, into the harbor, because we must realize that the time will come when the harbor will be seriously polluted, and perhaps spoiled, for pleasure purposes. In fact, Mr. Goodnough's report shows that the *waters* of the harbor are already seriously polluted, — so much so that harbor shellfish are no longer safe for use. Now, from any high standpoint,— from the standpoints of the public health and of the general welfare of a great seaboard city, with hundreds of thousands dwelling along its shores,— the sanitary condition of a harbor like this is a matter of very great moment.

The purity of Boston harbor is a very precious possession to the people of this neighborhood. The existence of the harbor

originally determined the situation, and its unrestricted use has ever since largely determined the welfare of Boston and the cities and towns in its immediate vicinity. The population dwelling upon its shores ought to be able to look forward to a larger and more wholesome use of the harbor rather than to a diminished and more dangerous use of it. For as population accumulates upon the land, the harbor, especially in the summer time, should forever remain, and ought still more to become, a playground as it were for the people; and even if sewage deposits do not greatly multiply, as there is reason to believe that they may not, yet boating will increase and fishing and bathing will go on, and if these cheap and wholesome entertainments are cut off, and if typhoid is brought back from the harbor or along the shores and planted among the people, Boston will suffer, and will continue to have a higher typhoid than any city ought to have.

Many explanations have been sought for the comparatively high typhoid of American cities, and we have found some of the explanations in oyster pollution, and some in our carelessness about water supplies. I daresay that some typhoid may come from cases brought by bathers and secondary cases given by them to their neighbors. But whether this be so or not, Boston harbor is a wonderful inheritance and a precious, a priceless possession to the people of this neighborhood, and no one can look with tolerance upon the idea that it is going to be spoiled or so seriously polluted in the future as to be unavailable for cheap and desirable recreation purposes. The time must come when something will have to be done with the sewage better than is now done; and the work at Lawrence, and the work at Columbus, and the work at Baltimore, and especially the work we have been doing in Boston upon this local problem, ought to contribute materially to the solution of that problem and to the ultimate conservation of the harbor.

We believe that our work does tend in this direction, and although a good deal of time and a good deal of money have been spent, we believe that the end which has been reached is thus far satisfactory. It is probably not final. New methods of purification will perhaps arise and more economic plans for sewage treatment. But something surely must and can be done in this direction.

Our work upon the *disinfection* of sewage and sewage effluents during the last few years is particularly novel, interesting and hopeful. It seems now entirely possible to protect the waters of our harbors and possibly of some of our rivers in ways

that we did not anticipate five years ago. And such disinfection, when combined with a reasonable organic purification, promises much from the sanitary as well as from the engineering standpoint.

You can readily see how very valuable this sort of work is to students, — to have a demonstration of work of this kind going on within easy reach of the Institute laboratories, — so that our young sanitary engineers and our young civil engineers and our young sanitary biologists and sanitary chemists can actually come into personal contact with such experiments, can see and appreciate these big municipal problems, and can get, themselves, a chance to do some little piece of work in connection with some portion of a great scheme. All this means, of course, a very valuable educational asset. We are particularly proud that our Institute has been able to do this work, and I believe I am within the truth in saying that it is the only educational institution in the world which has an establishment of this kind, operated under such favorable conditions, and offering such opportunities to young scientific men and engineers.

But to return to the point where I started, let me say that we are all greatly pleased that this Sanitary Section has seen fit to listen to our paper and that you have turned out in such goodly numbers to hear it. If now you will give us your perfectly frank criticism we shall value that even more highly. We know very well that there is room for it and we shall appreciate your criticism even more than praise.

Mr. R. S. Weston. — Mr. President, I understood Professor Winslow to say that the currents in the harbor are sufficient at all times to dispose of the suspended matter, in the effluent from the trickling filter, and I should like to ask whether that is in accord with the general belief that the current at the bottom or near the bottom of the harbor is very sluggish.

Professor Winslow. — I based my opinion on the investigations of the State Board of Health in regard to present conditions, which I understand indicate that there is no serious accumulation taking place. The effect would be the same with the trickling effluent; that is, there would be neither increase nor decrease of the problem as regards suspended solids. I have never seen any evidence and have never heard any evidence of a sound character to the effect that there was appreciable sludging up of the harbor due to sewage at present.

Mr. E. S. Dorr. — One thing occurs to me to ask Mr. Winslow, and that is, whether his experiments wouldn't lead him to

believe that a simple economical treatment of crude sewage, enough to effect a practical sterilization, with the under water discharge, wouldn't be sufficient for the present and for quite a period in the future; that is, whether it would not effect a very material improvement over the present discharge and practically be sufficient, without going to the expense of building trickling beds, which seem to be out of the power of the city financially to accomplish at present.

PROFESSOR WINSLOW. It is, of course, entirely impossible for us to say what the city can or cannot do in these premises. But I am very glad that Mr. Goodnough has brought out other phases of the situation and laid emphasis on them. We appreciate fully that the Moon Island outlet is only a part of the larger problem of Boston harbor. It is important to do the biggest things first, whichever those may be. We have only considered the Moon Island outlet because that was the particular problem given to us to study. At that outlet, I believe, it will ultimately be necessary to bring about the complete purification of the sewage; I mean purification, both organic and bacterial. By ultimately, I don't mean this year or next year, or even five years hence, perhaps. Ultimately I think we shall have to take both organic matter and bacteria out of Boston harbor, but I think, of the two, probably bacterial purification is the more important. As we pointed out in the paper, Professor Phelps and I believe this can be effected at a cost of $110 000 a year approximately, while complete purification will cost $250 000 a year. Which of those two plans, if either, the city of Boston is able to adopt at present, or will be able to adopt in the near future, is a question which we cannot presume to decide. Chemical disinfection will remove bacterial pollution at Moon Island. We have suggested that chemical treatment alone is feasible before the other plan is taken up. I don't believe, however, that chemical treatment alone will be a complete solution of the difficulty. Some time we shall have to demand organic as well as bacterial purification.

MR. W. S. JOHNSON. — It seems to me that this paper is a distinct contribution to our knowledge of the subject of sewage disposal. It is particularly interesting to note that the results of the experiments made at Boston and with Boston sewage differ so greatly in many respects from the results of careful experiments at other places and with different sewages, showing the absolute necessity of a thorough knowledge of the sewage to be dealt with. The conclusions with regard to the septic tank, for

example, differ greatly from the conclusions at Columbus. The Massachusetts State Board of Health has many times been criticised for its attitude in regard to the use of the septic tank in Massachusetts, but it would certainly seem from the results of these experiments, and from the results in other places in this vicinity where the septic tank has been tried, that the board has done a great service in preventing the general introduction of septic tanks in Massachusetts.

Prof. E. B. Phelps. — It has occurred to me that perhaps a word about this suspended organic matter which is prominent in this discussion might not be out of place. If any of you should come to our station and see some of those effluents side by side with the crude sewage in bottles I doubt very much whether you could pick out the effluents. In appearance, at least, you could not tell them apart. If you smelled them you'd find the effluent was sweet smelling and could readily be distinguished from the sewage. The fact is that the effluent contains about as much suspended matter as does the sewage, and to the sight it is not improved. That fact is the very salvation of this process. Contact filters, we have learned, are going to fill up. And there has been some question about the permanency of the trickling filters. But the very fact that trickling filters give out as much suspended matter as they take in seems to be their salvation, and we have every reason to believe, after two years of close watching of these filters, that under local conditions and with the problem in hand, these filters are reasonably permanent and will not be liable to any serious clogging.

Now one is apt to get an erroneous impression if you let the matter rest there. You have got to distinguish between those two kinds of organic matter. I want to emphasize the fact that the suspended matter that comes out is not in any sense the same material that goes in. It is altogether a different thing. It is not the same stuff. And that is particularly illustrated by the fact that during a portion of the year we stored some of that material in the filters and at the end of several months the suspended matter coming out was in excess of that which went in. We have considered somewhat superficially the question of disinfection of crude sewage. That did not appeal to us at first. It is beginning to appeal to us more and more, and we are quite satisfied now that there may be places and conditions where disinfection of crude sewage is called for and where that alone would be sufficient. Our experiments are rather meager on that particular point. We have been pretty thorough on the other

matter of effluents. The experiments that we have carried out have indicated the necessity for about twice as much chlorin in the former case as is called for in the latter. It is the organic matter in the sewage which uses up this chlorin before it can get in its work as a disinfectant. We have carried out some work in New Jersey, at the town of Red Bank. We have been disinfecting septic sewage there all summer, and the septic sewage seems to be still more oxidizable and uses up even more chlorin than does crude sewage.

It has been my good fortune during the past year or two to have been more or less closely associated with the work in other Eastern seaboard states, and it is possible that their experience may furnish some indication of the future needs of Boston. Baltimore is now building one of the finest systems of separate sewers and drains in the country. By legislative enactment it is provided that sewage should not be discharged from Baltimore into the waters of the harbor or Chesapeake Bay until it has been purified to the highest possible degree.

As a result the sewage commission of that city through its chief engineer, Mr. Calvin Hendricks, is now making an elaborate study of purification processes and is considering the matter of disinfection.

By a mutual agreement between the authorities of New Jersey and Pennsylvania, steps are being taken on both sides of the Delaware toward the cleaning up of that tidal water. The cities of Camden and Trenton on one side and Philadelphia on the other have each been notified that within a certain limited time sewage purification works must be installed. The New Jersey cities have been given four years, and Philadelphia a somewhat longer time in which to prepare plans.

In New York a commission has, for the past three years, been investigating the condition of New York harbor. It is generally conceded that some steps must soon be taken there. One of the consulting experts of that commission told the speaker but recently that, in his opinion, disinfection was a feasible and the most practical solution of their problem. In addition to the work on the lower Delaware, New Jersey has adopted a policy of rigidly excluding sewage from its ocean front and tidal waters.

It is thus plain that our work is neither academic nor untimely, but simply well in line with what is being done and thought out in other states, and for other great seaboard cities.

A Member. — I noticed that Professor Winslow said his

trickling filters were 8 feet deep. I would like to ask him how much additional head was taken by the trickling device.

Professor Winslow. — Either of the sprinkling devices will work satisfactorily with a 4-ft. head over the surface of the filter, but will work still better with a 6-ft. head when that is possible. Incidentally I may say that the depth of 8 ft. allowed for our filters was probably excessive. We have made our estimates on the basis of 8-ft. beds and 4-ft. head over them, but in the next two years we hope to find out whether a 5-foot bed will not work equally well. Experiments made on our old filters by taking samples at different depths indicate that a less depth than 8 feet is quite satisfactory. But we don't feel it is quite safe to make that conclusion definitely as yet.

Mr. George A. Carpenter. — There is one point upon which I am not quite clear. In his paper I think Professer Winslow referred to his screening as at present carried on as through bars about four inches apart, and I understood him to say later in the paper that he thought screening through a finer screen more desirable. I wanted to ask Professor Winslow how fine a screen he thought would be most advantageous, and whether his experiment led him to believe that the greater amount of matter that could be taken out in that way, thus relieving the trickling filters, the better.

Professor Winslow. — I should have said that the bars were ½ in. apart in our experiments. I spoke of more careful screening, in comparison with the present system, not at our experimental station, but at the Dorchestor pumping plant. I don't think I should be prepared to say just what size screens are necessary in this case. Our idea is to remove large floating particles and inorganic solids, street dirt, etc., but not to remove the finely suspended organic matter in the sewage.

A Member. — What is the practical working out of this process of adding a disinfectant to the sewage? If it was on a larger scale, would it be necessary to have auxiliary tanks or anything of that sort to apply this to the effluent?

Professor Winslow. — In this particular case it would not be necessary, because the disinfectant could be applied at Thompson's Island and would be thoroughly mixed by the time it reached Moon Island and could then have an additional storage period in the existing tanks at Moon Island.

[Note.—Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by March 16, 1908, for publication in a subsequent number of the Journal.]

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THE POLLUTION OF WATERS AT COMMON LAW AND UNDER STATUTES.

BY CHARLES F. CHOATE, JR., ESQ.

[Read before the Sanitary Section of the Boston Society of Civil Engineers, December 4, 1907.]

Mr. Chairman and Gentlemen: I want to thank you for the compliment you have extended to me in asking me to speak to you to-night. I assure you that I appreciate it. As I look about this board and see the faces of men whom I know have been through great fights with men like Mr. Goulding and Mr. Pillsbury and Judge Bumpus and Mr. Morse and others of that class, I need not tell you that I feel diffident in attempting to discuss before you those principles of law which must have been involved in nearly all of the work that it has fallen to your share to do. While diffident, however, I was not unwilling to attempt the task of some discussion, because I am a beginner at it and interested in it. I might illustrate my position, if you will permit me, by a story. You may have heard the story of the Scotch gamekeeper. If you have not, I will tell it to you.

One of our criminal rich,—of whom the number is growing less and less, and who will soon, probably, be extinct,—while in possession of a considerable amount of predatory wealth, was fortunate enough to be able to lease a shooting estate in Scotland, and hired a Scotch gamekeeper. He noticed that the gamekeeper always wore a hat or cap that pulled down over his ears. He never felt particularly like inquiring why he wore it, but still it attracted his attention and aroused his curiosity. On returning the next season he found his gamekeeper there but without

the cap. Instead of the old cap that he had pulled down over his ears, he found him wearing a little dickey that just perched upon the top of his head. He said, "Why, Sandy, that is a peculiar kind of hat. What has become of your old cap?" And the gamekeeper said, "Well, I haven't worn that since the accident." "Accident?" said the man. "I didn't know that you had met with an accident." "Have you not heard?" said Sandy. "Well, it's this way. One of my friends asked me to have a drop to drink and I didn't hear him."

Well, now, I feel an additional embarrassment in speaking to you to-night on this subject because I see upon my left a most generous opponent in some litigation in which I have recently been engaged, and upon my right the representative of the attorney-general's office, and I want to premise any remarks I make with this stipulation, that nothing that I say to-night shall be taken as an admission in any proceedings in which I may be involved hereafter.

Now, I was told since I came here that it was understood the subject upon which I was to speak was expert testimony. But I hope you gentlemen didn't think I had the temerity in this audience to speak upon that. The subject which I had selected at the suggestion of your chairman, it may be a paradox to say, is possibly a dry one, but it seemed to me that it naturally fell into principal divisions: first, the pollution of fresh waters, which is always capable of one or more subdivisions; and secondly, the pollution of tidal or salt waters, ocean waters.

Now, with reference to fresh waters. Of course those problems which we have to deal with involve, first, running waters, rivers or streams navigable and non-navigable, as to which the rights and liabilities are slightly different; and, secondly, ponds, private or great ponds. By great ponds I mean those which by law are so classed — ponds about or exceeding 10 acres in area, which by law are known as great ponds and which by an old ordinance of the colonies were made the property of the state, the Commonwealth. And dealing first with the common law with reference to the rights of individuals and municipalities in running waters, I think the law can be generally stated as it has been stated, fortunately for us, in a recent case decided by our Supreme Court, the case of Parker against the American Woolen Company. That was a case which involved the question of which Mr. Safford has just spoken — the pollution of a running stream, a non-navigable stream, by mill wastes. And the whole question and all the authorities in this

country and abroad touching the rights of mill owners to discharge mill waste into running waters, and the rights of riparian owners below to prevent that discharge, were discussed and settled.

Very briefly stated, the rule the court laid down in that case was this: that every riparian owner — and by riparian owner you will understand I mean an owner of land bordering upon a running stream — every riparian owner had the right as an incident to his ownership of land bordering upon a running stream to have the water come to him in its natural flow unpolluted except by a reasonable use of it by others. As an owner of that land bordering upon the stream, he possessed the right to make a reasonable use of the water. Every other man who owned land bordering upon the stream had the same right. The existence of that same right in all individuals who owned land necessarily, sooner or later, brought them, in the exercise of their rights, or would bring them, in the exercise of their rights, in conflict with each other. And there the law enforces something in the nature of a compromise and establishes the principle that every man can use the waters of a running stream in the exercise of his own rights, but subject to the limitations that in the exercise of those rights he shall not interfere with the rights of other individuals. That is not at first blush an illuminating definition.

But possibly illustration makes it plainer exactly what the court means. The law on this particular point is probably the oldest and best-developed of any portions of law which deal with this subject of rights in waters and the invasion of those rights. And from early times a man who owned land bordering upon a stream was held to have the right to use the waters of that stream for reasonable domestic purposes — for washing, watering his cattle, irrigating his land, bathing, fishing and for such things as were incident to the ordinary domestic occupation of land; always, however, subject to the limitation that he should not substantially or appreciably diminish the flow of water by what he used for irrigation purposes, and that he should not to any appreciable extent introduce into that stream by his use of it any noxious or improper or unhealthful substances.

Now you will see, starting with the domestic uses, that introduction of noxious substances into water might continue in the less thickly settled districts almost indefinitely in point of time without appreciably affecting the quality or the quantity of water in the stream. Mere bathing, mere watering of cattle

in a stream, probably domestic washing, fishing of course,—many of those things which would now instantly and properly be prohibited in public water supplies, would be regarded as not appreciably affecting the quality of the stream, the self-purifying principle in every such stream of water being considered sufficient to prevent anything of serious consequence from following.

The right has always existed, and is possessed and has been possessed by an owner of land bordering upon a stream, either to sue for damages if the quality or the quantity of the water in the stream has been affected by an upper owner, or to go into a court of equity and obtain an injunction. But you will notice in contrast with what I want to call to your attention later that the law has confined itself — the common law has confined itself— to the protection of property rights as distinguished particularly from those measures which would protect the public health or prevent the creation of a public nuisance.

Many instances have arisen which have tested this principle which the courts have laid down in ways which have raised difficulties for the courts. For instance, the erection of a saw mill has usually been followed by the turning of sawdust into the river. The question has been presented to the courts as to whether that is a reasonable use to make of the stream. It is a discharge of a waste, not noxious in itself, but might become so if used to an unreasonable extent, and may appreciably affect not only the flow, but the quality of the water. Usually, however, that has occurred in localities which have been thinly settled. Naturally we find the lumber mills in thinly settled districts, and it has not, therefore, been difficult for the court to say that for such regions as that such a use was not an unreasonable use. And the principle is always to be applied and always is applied by our courts with reference to all the surrounding circumstances of the cases involved.

A very recent case in Pennsylvania possibly strained that doctrine to its limit. The principle has been discussed here in Massachusetts, but has not really been accepted or rejected, and a case is never likely to arise here. In Pennsylvania some of the coal mine owners pumped the water from their mines and allowed that water to run down over the surface into a natural stream. Of course it ruined the quality of the water for domestic purposes. Probably with a desire to protect those interests, which were the prevailing interests in the state, the courts were led to hold that that was not an improper use, though upon principle it seemed to deprive every lower owner of every other

use of the stream except that use. It was practically a use for drainage purposes and practically prohibited any use of it for domestic purposes.

The same principles which the courts have adopted with reference to running streams and the same remedies are, of course, available to the owners of private ponds. I mean to limit that definition to those ponds which are wholly the subject of private ownership, and also to limit it to natural ponds. Of course, that is an exceedingly small class in number — ponds not 10 acres in area. With such ponds, you appreciate, there must be always some owner or owners of the whole, that is, of all the soil underneath the pond. It may be in one or more owners, but there must be owners of the soil underneath. If there are more than one, the rights of those several owners, I take it, would be exactly analogous to the rights of owners bordering along a running stream. Each would have the right to use the water probably for boating or bathing or fishing over that part of the bottom which belonged to him. Each would undoubtedly have the right to cut ice. Neither would have the right to discharge into that water any matter which would prevent his neighbor or adjoining owner from using the waters of the pond for such purposes, namely, for proper domestic purposes, as I have just described. Undoubtedly, the right would include the right to water cattle, though that might involve some pollution which would now be prohibited, or could be prohibited, by statute. At common law, undoubtedly, I think that would be a right incidental to the ownership of the land. The right to bathe, I think, unquestionably would be one the owner might enjoy.

Taking, then, next, the situation of great ponds, that is, ponds in area above 10 acres, we find this situation: In 1647 was passed what was called the Colonial Ordinance. There were many others, but this one has always been called *the* Colonial Ordinance. It provided that no town should be able to grant to any individuals any rights of ownership in ponds exceeding 10 acres in area, but that these ponds should be the property of the commonwealth and should be held always for the enjoyment of all the individuals of the commonwealth for fishing and fowling. And a curious provision follows to the effect that every individual should have a right of access over the lands of others to those ponds, providing only that in getting access he did not have to cross any man's meadow or corn land. Now that ordinance was repealed by the repeal of the Massachusetts

charter, that is, the Colonial charter. But our courts have held that the principle that was involved in it has become a part of the common law of this commonwealth. So that at common law those ponds in excess of 10 acres in area, unless granted before that time to individuals or to towns, became, and have been ever since, unless granted away since, the property of the commonwealth for those purposes. Whether the right still obtains to cross any other man's land to reach those ponds, provided you do not cross his meadow or corn land, the courts have never had occasion to decide. But it might be interesting for some of us to try that some time and raise the question.

The right of the public in those great ponds — and bear in mind I now speak of those only which remain the property of the commonwealth and have not been devoted to purposes of any public or municipal water supply — the rights of the public in those ponds, a member of the public, any one of us who can get access without raising any question of trespass, is to boat, to fish, to fowl, to skate, to cut ice; in short, to use those ponds in the exercise of that public right as an individual as distinguished from any right which he has as owner of land, or as anybody else to exercise those rights, providing that by so doing he does not interfere with the same rights which are vested in everybody else.

Of course, the existence of the right to do those things in others as well as the sort of stewardship of the commonwealth which holds those ponds, as it were, in trust for all of us citizens, involves this necessary conclusion: that no man in the exercise of his public right as an individual citizen of the commonwealth can do an act with reference to the waters of those ponds which would interfere with the enjoyment of the same rights in others. And upon that principle, of course, no one could turn sewage or any noxious substance into any great pond without immediately involving himself in a controversy with the commonwealth. I take it that the law is reasonably plain that the remedy is not invested in other individuals of the public here, but is invested in the commonwealth and would have to be enforced by the commonwealth's law officer, the attorney-general. You have in mind, doubtless, that principle of law which is to the effect that the private individual has no remedy, no personal remedy, for a public nuisance; that is, for the invasion of a public right. If, for instance, on leaving the club and going home we find some man without license has dug a trench across the street which obliges us to go around, or put

up a barrier in the street which obliges us to go around, none of us has any private action against him, that being a public nuisance which is an invasion of the rights of the commonwealth, and those rights must be enforced against him by the proper law officers of the commonwealth. But none of us, as an individual, has any private remedy or any right to recover damages.

So, with reference to a great pond, if we were deprived of our right, by pollution of its waters, of its use for bathing or boating or fishing, none of us would have a private right to recover and would have to seek enforcement of our rights through the law officer of the commonwealth.

Probably the most interesting aspect of this question of pollution arises out of the relations to it of municipalities — those questions which involve the right of towns or cities to turn drainage or sewage of any kind into running streams. Now this principle seems to be established beyond any question that the drainage of streets in towns or cities in a natural watershed of the stream may be turned into that running stream without anybody's having any right to stop it or to recover any damage for it. You see in substance what that is is only collecting in your street gutters and drains the natural rainfall on a given area, and discharging it more quickly than under natural conditions it would have been discharged into the same drainage outlet. So far as the operations of the municipality are confined to that they are lawful. The mere fact that the discharge is rendered quicker and perhaps greater by the fact that the water as it falls is collected in gutters and drains, and discharged without opportunity to evaporate or soak into the ground, even with the collection of matter in the streets and on the surface of the streets into the running stream, is not a violation of the rights of any riparian owner below. But the right to discharge the sewage of a city into a stream is quite a different matter. And that has to be viewed from two aspects.

An old case which may be familiar to some of you here, and which is often cited as authority, was a suit brought by a man named Merrifield against the city of Worcester. Worcester had discharged sewage into Mill Brook for some years without authority of statute, and Merrifield brought an action to recover damages against the city for injuries to his property below on the stream because of that discharge. The court in the case decided that the city was not liable in damages because of that act, but that decision would be nothing more than this, that in

an action of that kind a city, which is a creature of the statutes passed by the legislature, and can act only by authority of the legislature through its charter, cannot be held liable to pay money damages because of such an act of the city. But quite a different consequence would have followed had Merrifield in that proceeding adopted a different course. I take it if, instead of seeking to recover damages, he had gone to a court of equity and had shown that this injury resulting from turning sewage into the stream which flowed by his land was a continuing injury, a detriment to that property, and was not warranted by any statutes giving the city of Worcester the right to maintain it, he could have obtained an injunction against the city and have prevented the continuance of that pollution. So that I think I may fairly state that, short of such a case as I shall speak of in a minute, any individual who owns property on a running stream can prevent the pollution of that stream, whether it is caused by an individual or a set of individuals in the shape of a corporation or a municipal corporation, unless that pollution has been continued for a period of more than twenty years, so that a right has grown, or unless it is authorized by special statute.

Taking those questions which occur to me now as raised by Mr. Safford's introductory remarks — the cases that arise from the discharge of manufacturing wastes into running streams — it must necessarily follow from the principles which I have already called to your attention, and which I think our courts have laid down quite strongly and are ready to stand by, that it is of no consequence what the character of the substance discharged into the stream is if the result is that substantial and appreciable pollution occurs, whether that be so exceedingly noxious a substance as city sewage, or whether it be a substance like acids, or waste from a paper mill, or wool scourings from a woolen mill — those things which appreciably change the character of the water in a running stream are unlawful and can be prohibited by our courts. And they can be prohibited whether done by an individual or a private corporation or a public corporation. The only right to pollute water which can be obtained, and which is recognized as a right, is granted by statute, and I take it must involve the payment of damages for harm done, or a right which is acquired by prescription, as it is called, that is, by the use for twenty years under a claim of right without anybody's objecting to it, just as you can get a right of way across any man's land.

You notice still that all these questions I have been asking your attention to involve property rights, except, possibly, that which involves the rights of individual members of the public in great ponds. Passing from that division of the subject for a moment, let me ask your attention to another division of it which I think has been less discussed heretofore either among engineers or among lawyers than the one of which I have just been speaking; and that is the pollution of tidal waters. That must be a question which is going to engage engineers as well as lawyers very closely in coming years. And it is going to be a very large and serious question, it seems to me. Now here are immense sewers constructed and being constructed throughout the state, collecting sewage from all the larger cities and towns and discharging it into the harbor or not very far from the harbor and a great many private properties. There has been in this city and many other cities, noticeably in New York, a system of garbage disposal which sooner or later is going to attract the attention not only of engineers, but of lawyers. Pretty soon people who begin to feel the effects of those things are going to inquire of the lawyers what rights they have.

Now I take it there is this distinction between the right to have your tidal or seawater free from pollution and the right to have running water in streams or ponds free from pollution: Every man who owns land bordering on a stream possesses a property right, a right to have the water kept free from pollution, which is a right incident to his ownership of the land. It is not so with reference to the right to have one's ocean water kept free from pollution. The same ordinance that I spoke of a few moments ago, the ordinance of 1647, extended the ownership of every individual who owned land along the seashore from high-water mark, where before that time the law had placed it to mean low water. That is, it gave to the owner adjoining all the land which lay between high water and mean low water, that is, all the land in effect that is covered by the ebb and flow of the tide. Beyond that, beyond mean low water, the bottom is the property of the commonwealth, at least as far as we are interested in it. I won't say how far, but as far as we are interested. Now there is no ownership in the water. Everybody has a right to use the water for purposes of navigation or fishing or bathing if he can keep his feet off the bottom and not commit a trespass. If the tide is up, anybody can row or sail a boat in the water that stands over the flats which extend from high water to mean low water. But nobody can go there when the tide is out without committing a trespass.

Now, how does that leave the owner of property bordering on the sea if either an individual or a municipality insists upon turning sewage or dumping garbage into those waters in such a way as to become a nuisance or to create a stench upon that property? And every one of you probably knows numberless instances where that is done without thinking. Many of our citizens who own seashore property have run their house drains down into the sea. And here are all the large cities turning their sewage into the sea not a great distance from the shore. This is particularly noticeable along the Jersey coast and at Staten Island in New York, where solid material from the sewage is constantly coming ashore. While no man can have a private action for damage unless he can show actual injury to his property, I take it that there is no question that if the offense reaches the stage of being a public nuisance there is a remedy. That is, it can be prevented. On that question of sewage our courts have already decided in the suit of Haskell against New Bedford that if the city turns sewage into New Bedford harbor and fills up a dock by accumulations deposited there, the owner of that dock has a right of action against the city and can enjoin it from pursuing that course. The same principle must be involved in those suits in which, I trust, all of you and myself may hereafter be engaged, which will be brought by those people affected by the sewage of the great cities of the future, which will not only affect the lands fronting upon the sea, but must, unless some different method of disposal is devised, reach the stage of a public nuisance.

I have spoken so far only of those rights and remedies which exist at common law, and I mean now, before sitting down, to say a few words relative to that valuable supplement of the common law, the statute enactments, which one considering the question as left by the common law sees are absolutely necessary. I have called your attention to the fact that all the common law has undertaken to deal with has been property rights. It has not dealt in any practical way with the condition which menaces the public health, though I am not suggesting that under certain circumstances it might not. But for all practical purposes the development of the law has been in the direction of the protection of property rights. Now, as the waters of streams or ponds come to be used for the purpose of a public supply, there is a vast other different interest from the property interest which has got to be protected, and which can only be protected, sufficiently protected, by statute enactments. For instance,

this city takes a great pond for water supply, like Lake Cochituate. The question immediately arises whether the residents of that neighborhood have still the rights to boat and to bathe and to fish in that lake. The guardians of the supply believe it is not safe to permit the indulgence of that right. If they have got to resort to the somewhat slow method of the common law to obtain redress, or to prevent individuals from indulging in those rights, the public health may be seriously menaced meantime. For cases such as that you will see a statute is necessary, directly to prohibit, in waters used for water supply, the indulgence of those rights or privileges which are possessed by an individual or a land owner at common law, and to provide a method of speedy enforcement; and for this purpose the statutes have given us the aid of criminal law for the purpose of protecting the public health. Now, in two ways that has been done, either by passing laws directly forbidding the doing of certain acts with reference to the waters themselves, or investing in certain boards, as the State Board of Health and the Metropolitan Water and Sewerage Board, the right to make and enforce regulations with reference to bodies of water used for purposes of water supply. A very interesting question was raised and argued at the last sitting of our Supreme Court as to whether there existed in a natural pond, a great pond like Lake Cochituate, which had been taken and used for purposes of water supply, the right to boat upon that pond when the body in whom had been invested the guardianship of those waters for a section of the people of the commonwealth had prohibited such a use. And the court held that such regulations were valid and that in the face of them the former existing public right or individual right to boat and bathe in waters of great ponds had been lost.

I am going to take the liberty for a moment before I sit down of departing from that subject to suggest two rather interesting questions which have come up, and which I thought might interest you from an engineering point of view, and which have been dealt with by the courts. They relate to waters, though not strictly to the sanitary end of the subject. One was raised in a case recently tried in Worcester and involved this question: A man owned a water privilege on a river. Above him were four or five other privileges, and by privileges I mean reservoirs where there was power developed. For many years it had been the practice of all the owners of privileges upon that stream to run their mills in the day time, say for eight or nine or ten hours a day, and to let the water down during the hours

of daylight and store it up again at night. By and by one of those upper owners began to manufacture paper and also to manufacture electric light, so that it became a business proposition for him to use the water on the stream every hour of the twenty-four, and instead of storing it up over night, as a result of which lower mill owners would get the benefit, he used the water all the 24 hours and there was no accumulating storage. The lower mill owner brought an action against him to compel him to hold the water up at night, as had been the practice for many years — I'd almost say for generations of mill owners — and immediately the question was presented whether, the custom apparently having been adopted and practiced for many years, one mill owner could depart from it to the detriment of another, or whether he was bound by that custom and must, for the advantage of those below him, abide by it. And the court went back to the old principle which I have attempted to enunciate, that every man was entitled to have the water of a running stream come to him in its natural state, and that meant it was to run all the 24 hours and if it was dammed up by anybody, that was something of which you got the benefit; but if he chose to run it all the 24 hours you, by law, could not complain.

Another substantially new principle was raised in a case which I had the pleasure of trying, with Mr. Safford's assistance, and that was as to the right of a man who owned a privilege down stream, with two or three or half a dozen privileges up above, and whose privilege was taken, that is, seized, by the city or town, which had the right to do it, whether he was entitled to ask the courts to assess his damages at a greater amount because of the advantages he derived from his position on the stream from the storage of owners farther up. It being established by a decision of the court of which I first spoke that he had no right to require the upper owners to keep their dams up, the question was presented, had he a right to recover damages despite the fact that he could not make the upper owners keep their dams up, because his property, being lower down the stream, did possess the gratuitous and incidental advantages of making use of that storage as it was let down to him. The analogy was suggested, a building on this street. It has value because all around it there is business property and dwelling property. It is valuable because it has been selected as a locality in which people have and in all probability will continue to have business interests. And yet the owner of this property could not compel the owner of any of this adjoining property to use it for any specific

purpose, or to maintain any kind of building, or to continue to devote it to business or dwelling-house uses. Yet the principle must be plain that, inasmuch as this property will, in all probability, continue to be in the center of business activity, and the region around it will be devoted to those purposes, despite the fact that you have not the valid right to keep it so, there is unquestionably a value growing from those facts, to which you have not an absolute right, which gives to your property an added value, which has to be taken into consideration if it is taken away from you. And I am happy to say that the court sustains that proposition. I thank you very much, gentlemen.

DISCUSSION.

A MEMBER. — I would like to ask if the statutes have not changed the law regarding the acquiring of a right by prescription?

MR. CHOATE. — That is true in reference to the commonwealth. Between the years 1835 and 1867 an individual, and I should say also a city, could acquire the right to pollute a great pond. In 1867 that law was repealed so that now no one can obtain the right of prescription against the interests of the commonwealth in its great ponds. There is no statute at the present time which prevents an individual from getting the right of prescription against another individual. That is, to illustrate, if you own higher up on the stream and I own lower down, and you turn your house drainage into that stream for twenty years, you can acquire a right against me. Further down that stream empties into a great pond which has become a water supply. In that case you might acquire the right against me, but could not now acquire it against the commonwealth.

A MEMBER. — Has not the statute changed the size of a great pond to 20 acres?

MR. CHOATE. — I did not know it. I may be wrong.

MR. ALEXANDER LINCOLN. — I was asked yesterday to join in the discussion of this subject and came prepared to say only a few words. My acquaintance with the subject has been gained by being connected with the case of which Mr. Choate has just spoken — Parker against the American Woolen Company — in which I was associated with Mr. Whipple in behalf of the American Woolen Company. They conduct a woolen mill on Beaver Brook, which runs into the Merrimac River. The mill is situated near Lowell, and Beaver Brook runs into the Merrimac near Lowell, so that the locality is one where the water is largely

used for mill purposes. The pollution complained of was the ordinary pollution one would expect from a woolen mill. There had been at various periods wool scourings dumped there and dye stuffs escaped into the river and compounds of different sorts and acids. That was practically conceded by the company, but the difficult principle involved was whether they had not the right to pollute to some extent, and, if so, to what extent?

During the course of preparing the case for argument before the Supreme Court, quite an extended search was made of authorities for the law on the subject, and on our part we became convinced that the rule which ought to be adopted by the Supreme Court was very different from the rule which they finally adopted. Of course the position taken by us upon the question was a partisan one. It was not an entirely impartial and scholarly investigation which we made, but was with the idea of taking one side rather than another. However, the rule of law which it seemed to us should be adopted was the rule which may be stated in general terms as applicable to the use of water by any proprietor of land on the water, that he and every other proprietor may make a reasonable use of the water of the stream as it flows by his land.

That rule has descended from the common law of England centuries ago. At that time the principal use made of water was for domestic purposes, the watering of cattle, for drinking purposes and possibly to some extent the damming of the water for mill purposes, but of course to no such extent as in this country at the present day. It is true the courts at that time also did say expressly that no person was allowed to pollute the water of the river, but that seemed to be more a particular application of the rule that each person might make a reasonable use of the river than an entirely independent rule. That is, the courts at that time, having regard to the development of the country and uses to which water might reasonably be put, announced as a fact that a use of the water which polluted the water was not a reasonable use.

Coming to this country, however, which was in a different state of development, the courts from an early day took a somewhat broader view of the situation. In a number of jurisdictions questions arose, principally from the depositing of waste from saw mills and other like cases, where such pollution of the water was permitted. There was a case in New Hampshire and a case in Minnesota and also the case of which Mr. Choate spoke in Pennsylvania, a mining district, where the court decided that

water might be polluted by acid which came from mines and was emptied into the stream, that being a reasonable use of the water, having regard to the locality.

In Massachusetts the law appeared to be in rather a confused state. There were some decisions which announced the principle of the right to a reasonable use very strongly, and some in which it was applied where pollution in the form of deposit was permitted. In the case of Merrifield against Worcester, pollution in the form of sewage was permitted. Other cases in which it was said no pollution would be permitted were found. The general principle was announced by Chief Justice Shaw, who has a great reputation in the law, in terms which would be applicable to the pollution of a stream. He said: "In every case a riparian proprietor has a right to make a reasonable use of the stream which flows past his land." He further said that the question of a reasonable use is a question of fact; that is, a question to be settled ordinarily by a jury, and that in determining what is a reasonable use, the character of the stream should be considered, the character of the population, the density of the population along its banks, the wants and uses of the community; in a word, every question which would be considered in determining the question as to what the public policy of that particular community was or should be.

Those considerations were presented to the court. But the court decided in our case that no pollution is to be permitted which shall appreciably or noticeably affect the purity of the water with respect not only to manufacturing uses, but to domestic and even drinking uses.

Now it does not seem as if that was a very practical solution of the problem of the use of water for different purposes. At the present day no person wants to drink the water of any stream which he may come across. That should be regulated properly by statute or some commission; and, of course, in the large cities, the use of water for drinking purposes is regulated by commission. It seems to me that the manufacturing industries of the state should receive some protection and should be given some freedom of development and should be considered to be of more importance than the watering of cattle and agricultural uses which were formerly and may still be considered in some jurisdictions of paramount importance. But under the law as it stands, the use of water for mill purposes would seem to be considerably restricted. In many instances, as, for instance, the case of the conduct of woolen manufacture, it is

impossible so to conduct the manufacture that water shall not be polluted to some extent, so that if this rule is rigorously applied, it is hard to understand just how the manufacture of woolen goods can be carried on at all. In this case of Parker against the American Woolen Company the water cannot be entirely purified, although since that time a large set of filtration tanks and sedimentation basins has been constructed; but we understand that does not render the water of such a quality as to make it fit for drinking purposes.

There are two principal uses in such manufactures to which the waters are generally put. There is the use for carrying off waste — as a sort of sewer; and the use of the water for washing. It seems to me, particularly in the last respect, that it is very important that the land owner may be allowed to pollute the water to some extent, and unless he is given some freedom by statute it is rather difficult to see just where we shall end with regard to our manufactures.

Mr. Wheelwright. — I did not come here with anything prepared, but I have been very much interested in what has been said, having had a little experience in watching the pollution of streams and in trying to prevent it, and, I regret to say, not very successfully. I was much interested in what the previous speaker said in regard to the pollution of a stream by another manufacturer, because I have a similar case to deal with. There is a wool scouring mill above one of my paper mills which has been of great annoyance, and I feel they now recognize that we have some rights, and they have tried to remedy conditions, and from what I have heard to-night I am sure that my case against them is much stronger than I supposed it was.

The question of pollution is very puzzling, and one which every manufacturer must look upon as something which may come home to him, especially if he is located on the Neponset River. It is a question which, I think, the state will have to deal with as a whole, and establish some rules which have a greater measure of equity and justice in them than one seems likely to get at law.

Dr. L. P. Kinnicutt. — There has been a case recently tried in the Worcester courts that resembles the case of Parker against the American Woolen Company, only in this case the amount of pollution is much less than in the Parker case. The case I refer to is that of Honora McNamara *v.* David M. Taft. Mr. Taft owns a small mill in the town of Oxford for the manufacture of shoddy, which is situated on a small stream that flows

through pasture land owned by the plaintiff. The plaintiff's house and barn are not situated on the stream. The plaintiff claimed that the cattle, which, by the way, consisted of three cows, when in the pasture would not drink freely of the water on account of its being polluted by the waste products from the Taft mill, and asked for an injunction and damages. At the Taft shoddy mill no wool washing is done, and the waste from the mill consists principally of dyes, washed out from the goods after they have been speck-dyed. The testimony in the case was that the water in the stream as it flowed through the pasture was as free from color, taste and odor as some of the potable waters of Massachusetts, and neither chemical nor bacteriological examination gave any evidence of marked pollution. And, further, there was only very little difference between the character of the water at the dam before it passed through the mill and as it flowed through the pasture. The judge in his written opinion said that on visiting the stream he was unable to detect any difference in the color, taste or smell of the water at the mill-dam and of that at the farm. The injunction seems to me to be granted solely on the ground that the emptying of untreated manufacturing waste directly into a brook or stream is not a reasonable use of the stream. The case has been appealed to the Supreme Court of Massachusetts.

Mr. Choate. — I should say that the case that Dr. Kinnicutt has described shows the extent to which the rule I have tried to make plain might be carried. Of course there seems to be a practical injustice done there, principally because of the great inequality that exists in the value of the farmer's right or interest as compared with the right or interest of the mill owner. Now it may be that in view of the fact that our state has become so largely a manufacturing state that the continued recognition of the old common-law principle, which began in an agricultural country and was applicable strictly to the agricultural country, ought not to be extended or continued any further. And yet if one is to attempt to define and assert a principle, I think it is rather difficult to arrive at any other and do justice to everybody. The purpose of the principle seems to be to establish every man's right to have the water come to him in its natural flow, both as to quantity and quality. If you attempt to limit or cut down that rule in one respect, you will soon find yourselves in a position where you are asked to cut it down in another. To illustrate:

An upper owner might find it necessary in the conduct of

his business to actually consume a substantial amount of the flow of a river, and by that result substantially diminish the flow of the stream without interfering with its quality. The argument in your mind is this: Are not the interests of those in a given case who want to consume water of such paramount importance that they ought to be permitted to do that rather than to sacrifice them to the rights of a lower owner whose real interest is comparatively small. It is just such hard cases as that which are apt to test a principle to its utmost, and unless you adhere to it in every kind of case you will find that you have not any principle left at all.

Now I should say that the case that Dr. Kinnicutt described was probably decided on the theory that was advanced in Mr. Lincoln's case — Parker against the Woolen Company — and if that use by the Taft Shoddy Company was continued for twenty years they would then have acquired a prescriptive right to continue it indefinitely. They evidently were doing something with that stream that left it when they got through with it — after it passed through their land — in an entirely different condition from its natural condition. And if they continued to do that for twenty years they would then have acquired the right to do it. Now, if at the farmer's land below there was no appreciable difference in the water, that is, in its color, taste or quality, except to the acute perception of the cow, it seems rather hard to find the ground upon which the judge acted. Because I think the rule is that unless there has been an appreciable and noticeable difference, there has not been any invasion of a right. But suppose that we assume, for the sake of benefiting the larger interest, that we may invade that right a little, are we not at once cutting our cables and floating away from any principle at all? Until we are ready to take the other step and by some legislation say that the use of running streams for washing or for drainage for mechanical or municipal purposes is of such paramount importance that the rights of the agriculturist ought to be surrendered, hadn't we better adhere to the old principle?

A Member. — May I inquire of Mr. Choate in regard to the rights of the state to inland ponds greater than 10 acres, whether they still have rights as against mill owners?

Mr. Choate. — Well, sir, I think that is a question which is not very definitely settled in all its aspects. I think you can state possibly one principle of the law with reference to it with some certainty. I take it you have in mind a natural pond which has been partly dammed up, that is, whose area and capacity

have been increased by artificial means. Well, there are a number of difficulties that arise as to that. I think the law is quite plain that the rights of the public to boat and fish and bathe in such waters have not been affected. I think the right of the state to grant such ponds away to municipalities has not been affected at all. In the Watuppa Pond case at Fall River the court first laid down the rule that the commonwealth could grant away a great pond without paying any damages. For instance, in those cases as first decided the statutes authorizing Fall River to take the waters of the Watuppa Pond for city supply contained no provisions giving the mill owners any damages. It was only after a great deal of litigation and a great deal of very diligent work by the lawyers engaged in the case that it was discovered that the Watuppa Pond had come to the mill owners by actual grant that could be traced back to the Plymouth Colony, so that they were actually owners of that property by grant, and the ponds were never great ponds in which nobody had property rights except the commonwealth.

Another very interesting set of difficulties arises as to ponds of the character you describe, which is akin to the subject I have talked about to-night. Suppose a great pond which has been dammed up and its area increased is drawn down by the mill owners in the proper use of the water for their mills to an extent that leaves a considerable tract of margin around the border uncovered and unpleasant and possibly unhealthful. Has anybody got any rights, then? That question is very certain to be raised very soon, if not in this city, certainly in neighboring states. It has been raised in New Hampshire with reference to Winnepesaukee and Great East Pond. I know the attorney-general of Maine has been asked to begin proceedings to adjust the rights of mill owners on Salmon Falls River and Great East Pond, the head water of the river, which happens to be partly in Maine and partly in New Hampshire. Great East Pond was used for storage purposes for mills on the river as far back as 1825, and about 1841 or 1842 was dammed at the outlet and so substantially raised that a great many acres not included in the natural area of the pond were flooded. It happened within the last summer, and a number of years previously, that in dry seasons the water of the pond was drawn not only to its original natural level, but below, and in recent years all around its borders, because it is a beautiful country, people have built summer houses and they have found themselves so that between their houses and the margin of the water there was a long stretch of meadow bottom covered by old stumps which was very offen-

sive both to smell and sight, and created a very awkward and disagreeable situation. And the question immediately arose, What right had they as individuals to stop that sort of thing? The question will, I presume, be litigated before long. It must be reasonably plain, however, that if the mill owners have acquired the right there either by statute or by actual use for more than twenty years to raise the waters of a natural pond above their natural level that they are not violating anybody's legal right if they only draw them down to the natural level. Going beyond that point and lowering the waters of a great pond is a pretty questionable operation, and I should think it might involve mill owners who depend upon Lake Winnepesaukee in difficulties.

PROFESSOR PHELPS. — The state of New Jersey has given one of its commissions jurisdiction over tidal waters, so that commission may prohibit the discharge of any sewage into the ocean. I did not quite understand Mr. Choate's position in that matter, and I'd like to ask him whether that is legally within the powers of the state.

MR. CHOATE. — Please state that again.

PROFESSOR PHELPS. — Whether it is within the powers of a state to give a commission jurisdiction over the ocean front, so that it may prohibit new works and order old works taken out and purification works put in.

MR. CHOATE. — Yes, I should say there was no question that that was within the powers of the state. It is a regulation in protection of public health. A state, either for that or any other public purpose, may deprive you of any right in land. What would be involved in that case you suppose would be a private right, or a supposed private right, to drain into the sea, which might be taken just exactly as the whole estate might be taken. The principal question involved would be whether the state could do that without having to pay damages, and I'd hazard a guess that it could, because of the power invested in the state to exercise any reasonable means for the protection of its people.

MR. ARTHUR T. SAFFORD (from remarks as chairman in introducing the subject). — I wish to make the following comparison between the conditions thirty years ago and at the present time with regard to the pollution of the streams in this state. In a report * by William Ripley Nichols to the State Board of Health

* A report to the State Board of Health of Massachusetts. By Wm. Ripley Nichols and George Derby, M.D. State Board of Health, January, 1873.

of Massachusetts, January, 1873, page 91, is the following statement:

"It would thus appear that for the present the rivers of Massachusetts are not polluted to such an extent as to cause alarm, and yet neither the Blackstone River nor the Merrimac below Lowell would be recommended as a source of supply for a city. It is, however, to be borne in mind that our manufactures and, consequently, the population of our manufacturing towns, are rapidly increasing, and that in the case of the larger towns more efficient systems of water-supply and of sewerage are being rapidly introduced. The day is probably far distant, when we shall reach the state of things at present existing in the manufacturing districts of England, but, in many cases it will only be a question of time; it is hoped, however, that further examination may lead to suggestions which will tend to prevent the unnecessary abuse of running streams."

Thirty years later, in the State Board of Health Report for 1902, page 330, we find the following:

"Manufacturing wastes of various kinds are very important factors in the pollution of streams, and the present condition of one of the most grossly polluted streams in the state is due almost wholly to the discharge of manufacturing wastes into the stream and its tributaries. The manufacturing wastes which have the most serious effect in polluting streams and are most commonly met with in this state are the wastes from woolen mills, including the wastes from the scouring of wool and the washing and dyeing of cloth, wastes from tanneries, from paper mills, from shoddy mills, from print works and from rubber mills, silk factories and gas works.

"The wastes from the processes of wool-scouring usually contain very large quantities of dirt and organic matter of various kinds, and are very serious sources of pollution of streams at many places."

The change in conditions, indicated by these statements, makes the question of stream pollution a very important one; and while the details of the treatment of stream pollution will be left to the sanitary engineers, the question is essentially a legal one.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by April 15, 1908, for publication in a subsequent number of the JOURNAL.]

ANNUAL ADDRESS.

By Edward C. Kinney, President of the Montana Society of Engineers.

[Read before the Society at its Twenty-first Annual Meeting at Bozeman, Montana, January 11, 1908.]

Mr. President and Members of the Montana Society of Engineers: It is eminently fitting that you meet together one day in the year for the purpose of renewing acquantances, shaking the hands of old friends and comparing notes of the work you have accomplished. Your duties are located so far apart that for many of you this is the only meeting of the year and you enjoy to the full this opportunity.

You gentlemen belong to an order which, though not much more than a hundred and fifty years old, stands at the head of the progress of the world. You are leaders in the thought and action which promote civilization, as no other body of men has ever done. Much has been done by you in the past, and the possibilities yet to be accomplished in the future roll out before you far beyond the power of the imagination. Those of us who have been in this profession for a lifetime realize more and more the grandeur and nobility of the work. What a wonderful feeling of elation comes to one who has attacked some new problem in nature and has conquered it; has compelled some force of nature to become the servant of man.

Doctor Colgate has given the definition of engineering as, to devote oneself, to get at the bottom of things, to do things. Tredgold has defined it as the "art of directing the great sources of power in nature for the use and convenience of man." That is what you are doing, and can anything be nobler than to add to the happiness and comfort of men?

In this line some of you are producing copper, gold and silver from the earth with mighty machinery designed and constructed especially to fit the unusual difficulties of the work. This not only produces money wherewith to buy the necessities and comforts of life, but also the copper to construct the vast systems of transportation and transmitting power from the source of supply to the point of its necessary use. Others have been busy harnessing the mighty rivers with powerful bands and

compelling them to turn immense wheels to produce power for the use of their masters. Again there are others, who are far from being the least, who have spent their time tearing down mountains and building up valleys, moving rivers out of the way, and bridging other rivers, for the purpose of building railroads. These roads are an absolute necessity for the transportation of the immense business that your energies have developed.

There is no doubt that you engineers are the supreme motive force of modern civilization, because your work is dynamic and not static; because you have to be obedient to absolute and immutable laws; because in seeking out those laws and using them for the benefit of mankind you are freeing man, making him the master where he was formerly the slave of nature. By your inventions you are replacing the aching and strained muscles of manual labor by the tireless machine. There has been a tremendous advance in the social and business world, and while this advance has made the rich man incredibly richer, it has at the same time lifted up hundreds of thousands of men who, under the old conditions, would have known nothing but hopelessness. It has lifted out of utter degradation tens of thousands of others who are desirable citizens because of the work of you engineers.

The condition of the Montana Society of Engineers for the past year has been good. There has been a number of additions of new members and only one death, that of Mr. Charles A. Molson. The meetings of the Society have been well attended and the interest manifestly good.

The engineers generally over the state have been unusually busy until the latter part of the year, when the financial difficulties have caused some slacking down of the engineering projects.

MINING.

From the Helena District, Mr. F. L. Sizer reports as follows: The year just closing has been an unusually active one in mining throughout Montana, and certainly Lewis and Clark County and territory adjacent to Helena have had their share of prosperity. While the high price of lead and copper prevailed, producing mines were handsomely rewarded and the average price for these metals for the year 1907 will show a high level. Profit in mining, either actual or prospective, has stimulated further prospecting, has afforded employment to an unusually large number of men and has benefited all classes of tradesmen.

The scarcity of first-class miners in this vicinity (largely due

to the high wage scale prevailing in Butte) has made it difficult for the mine operator to carry out all of his plans to the best advantage. Material of all kinds has been almost as scarce as labor and hard to get promptly, thus delaying construction work. In spite of these drawbacks some notable progress has been made.

The Corbin District, 30 miles southwest of Helena, has been actively developed. Three mines have been shipping copper ore, presumably at a profit, and several deep shafts for prospecting purposes have been steadily at work.

The Rose Gold Mine near Jefferson has shown up a large amount of high milling gold quartz by recent work and will doubtless be properly equipped another season. Perhaps the most important newly-opened mine near Helena is the Spring Hill Mine in Grizzly Gulch, 3 miles south of the town. The extent of the vein of this gold-bearing quartz lode is as yet unknown, but certain it is that it is very large,—properly speaking, a mother lode,—and doubtless the source of most of the gold in Grizzly and Last Chance gulches. Since last February, when the present company became the owner of this mine, it has been actively developed, both lineally and to a greater depth, justifying the previous good opinion expressed of it and already showing ore in sight to an amount many times greater than the price paid for the mine.

Since September the quartz has been milled in the 20 stamp mill of the Whitlatch Mining Company, now under lease to the Spring Hill Mining Company and the tailings are now being treated by the cyanide process in a plant recently completed by the latter company, at Unionville, adjoining the stamp mill. The success of this enterprise has stimulated prospecting upon the course of the lode both east and west of the Spring Hill property, resulting in encouragement for further development both upon the ground of the Spring Hill Extension Company and on the Nonesuch Mine in Arastra Gulch, operated by John A. Rowand, as well as in the case of other individual operators in this immediate locality, all of whom are hoping to locate other pay shoots on the course of this great lode.

At Rimini, the Valley Forge has been a steady producer, and since the completion of their 4 000-ft. aërial tramway for delivery of ore at the railroad track, a regular output of 1 200 tons per month has been maintained. This is a silver lead ore carrying gold and has been sold to the East Helena plant of the American Smelting & Reduction Company. The increased ore bodies have

justified the management in starting to drive a new deep tunnel from the level of the railroad track which will ultimately cut out the necessity for the tramway, besides developing the mine to an additional depth of 500 ft.

In the vicinity of Marysville the Bald Butte Mine has opened new ore and has (rather unexpectedly except to those who have been keeping close track of it) resumed the payment of dividends.

The Bell Boy Mine and the General Grant Mine in Towsley Gulch have been operated and will surely make producing, paying mines. Some work has also been done on the old Blue Bird Mine, and the St. Louis Company at Marysville will shortly resume operations on this property.

In the Scratch Gravel district, 4 miles north of Helena, besides a number of prospects worked more or less intermittently, the Purnell Mine has been developed by a shaft 300 ft. deep, and since cross cutting has been done several promising veins with good values in gold and copper have been encountered.

Three miles west of Helena, just back of Fort Harrison, a very good showing has been made by the West Virginia & Montana Mining Company, and shaft sinking to a depth of 200 ft. is now in progress.

The Argo Copper Mine in Hell Gate Canyon, 28 miles northeast of Helena in Broad Water County, has been continuously operated and was shipping ore and concentrates to the Washoe Company in Butte until the recent shutdown necessitated finding another market. This mine has been developed by a winze 100 ft. deep below the tunnel level during the year and shows continuity of the size and value of the ore bodies above the main working tunnel. It is owned by the Eclipse-Argo Mining Company, and when the price of copper becomes more stable extensive improvements in equipment and further developments are contemplated.

In Avalanche Gulch, next east from Hell Gate, a similar property is now being opened by Spokane parties, and the development is said to be highly satisfactory. This copper belt is one of the most promising districts near Helena and has been a long time reaching even its present stage of imperfect development. In the Spokane Hills, south of the Missouri River and nearer to Helena, some prospecting on copper veins has been done. A number of other small operations are in progress, all of which add to the total of mine development very greatly, and with more settled conditions in business they will be actively

prosecuted and some of them will result in the opening of permanent producers.

The Butte District.

Robert A. McArthur reports as follows:

There has not been any great amount of work of engineering interest in the Butte district during the past year.

The underground development of the various mining companies of the district progressed steadily up to the time that the drop in the price of copper caused a cessation of activity.

At the High Ore Mine of the Anaconda Company the shaft reached a depth of 2 881 ft. during the past year, making it the deepest shaft in the district. It is the main pumping shaft of the Anaconda Company's mines and also of some of the adjoining mines.

At the Pennsylvania shaft of the Boston and Montana Company a new hoisting engine, boiler plant and steel head frame, together with the necessary buildings, have been installed. The hoisting engine was built by the Allis-Chalmers Company, has cylinders 32 in. by 72 in., a capacity of 3 500 ft. in depth, hoisting a total load of 34 000 lb., or a load excluding weight of rope, of 21 225 lb. The rope used is 1.5 in. round steel and the total weight of the engine is 264 tons. The boiler plant consists of 4 Sterling boilers of 300 h. p. each, with a steel smokestack 8 ft. in diameter and 175 ft. in height. The head frame is of the usual type of the district, being of steel 100 ft. in height from the shaft collar to the center of the sheave wheel, and is fitted with skip bins for the automatic dumping of the ore. Pockets for skips and cages are provided adjoining the collar of the shaft.

At the new Leonard shaft of the Boston and Montana Company the compressor plant was completed by the addition of two electrically-driven Nordberg air compressors, making three in commission. During the annual meeting a year ago the engineers visited this plant, only one compressor being in commission at that time. At the tramway shaft a new hoisting engine, a duplicate of the one at the Pennsylvania, has been installed, together with a new steel head frame.

The foregoing includes most of the work of any magnitude or engineering interest done in the district. There has been the usual amount of repairs and alterations and a great deal of work of installation and equipment at the numerous smaller development properties, but as a whole of very little interest from an engineering standpoint.

COAL MINING.

Mr. F. W. C. White reports as follows:

The only work of interest that has been done in the coal department this year has been the opening up of our properties in the Bear Creek field. Some time in May the first ground was broken for No. 1 mine, and to-day it is producing 500 tons of coal daily, with a capacity for 700 tons per day. At the same time we have been sinking a rock slope for No. 2 mine to tap the deeper veins in the field. This slope has already cut No. 1 vein at 350 ft., the intention being to continue it to No. 2 vein this winter, then to stop.

Altogether there are five, if not six, workable veins in the field, and the lands owned by the company are estimated to contain not less than 75 000 000 tons of coal, the greater part of which is tributary to the No. 2 slope now being sunk. So that No. 2 slope has a long life before it. Besides the mine work, about one mile of comparatively heavy grading for railway had to be built, besides yards for each mine. About 25 houses have been built for employees, the intention being to build about as many more next year. Ground has been leased to employees for building purposes, and at least 20 families live in their own homes, which are quite substantially built. The camp bids fair to become a model camp and is to be known by the name of "Washoe," a post-office of that name having been established. None of the permanent buildings have yet been placed for No. 2 mine, such as engine or boiler houses, the heavier construction having been stopped 3 months ago.

From Lewistown, Mr. Otto F. Wasmansdorf reports that the Central Montana Coal Company has been organized with 400 acres of very high-class coal. It is the intention to build a narrow-gage railroad to the mines to deliver the coal to Lewistown. The estimated tonnage of coal in sight is 3 000 000 tons. The road is 12 miles long and Mr. Wasmansdorf is the chief engineer.

The Chicago, Milwaukee & St. Paul Railway Company is opening up some very large coal mines near Roundup in the lower Musselshell Valley. It is already taking out a small quantity of coal.

WATER POWER AND ELECTRIC PLANTS.

Mr. M. H. Gerry reports as follows on the new dam at Hauserlake.

The dam is located at Hauserlake on the Missouri River, 18

miles below the Canyon Ferry dam of the Missouri River Power Company, and 18 miles from Helena.

Work was commenced on the dam in July, 1905, and completed ready for filling the pond on January 25, 1907. Transmission of power from the generating station commenced February 15, 1907, the time consumed in filling the pond being about 15 days. Water is backed up to the toe of the Canyon Ferry dam and also up the Prickly Pear Valley to within 8 miles of Helena, thus providing a very large storage of water to cover fluctuations in the flow of the river. The maximum head on the dam is 70 ft., and normal operating head is 65 ft. A foundation of concrete, with an upstream seal of Friested steel interlocking sheet piling, was constructed to support an all-steel superstructure of the gravity type, furnished by the Wisconsin Bridge Company of Milwaukee. All construction work, except the erection of the steel, was carried out by the Power Company's engineers under the immediate direction of Mr. M. H. Gerry, Jr., manager and chief engineer. A rock-filled timber crib, surfaced with timber, serves as an apron below the spillway, which is 500 ft. wide, the total crest width being 615 ft. A short open canal at right angles to the east end of the dam conducts the water to the entrances of 5 turbine penstocks, each 12 ft. in diameter, bedded in concrete, which dip directly into the power house. The power house is 53 ft. by 212 ft., with a steel frame, rock walls and reinforced concrete floors. A fire-proof curtain wall separates the generator room from the transformer and switching room. The installation consists of 5 pairs of 48-in. S. Morgan Smith horizontal turbines directly connected to five 4 000 h. p. Westinghouse generators; three 25-in. turbines connected to 300 h. p. exciters; and nine 2 750 h. p. transformers, together with necessary switching apparatus and accessories for raising the voltage of the power generated from 2 400 volts to 70 000 volts, 3 phase, for transmission over duplicate lines, 68 miles to Butte and 90 miles to Anaconda, where the power is rapidly supplanting steam power for all purposes in connection with mining and smelting, with a large saving in cost and an increase in efficiency and output under all the various conditions when it is used.

The Butte Electric and Power Company and its Allied Companies.

The following facts have been abstracted from a long report to his company by Mr. Max Hebgen. I should be glad to give you the whole of the report but it is too long for this occasion.

The Madison River Power Company has its generating plant at the head of the lower canyon of the Madison River, about 28 miles above its mouth. At this point the company has erected a dam about 65 ft. high which creates a lake covering an area of 9 sq. miles. The development here is, first, the old Nunn Station, having a capacity of 3 000 h. p., and the No. 2 power house, with 9 000 h. p. developed and 3 000 h. p. additional that will soon be installed. There is also the No. 3 development some 5 miles farther down the river, that has been begun and will be finished in a year or two, that will add 15 000 h. p. more. This h. p. is based on the minimum flow of the river, which is taken to be 1 100 cu. ft. per second, and the stored water, that will bring the available flow up to 1 600 cu. ft. per second. In addition to the lake that has already been created on the Madison River, there is to be another reservoir built in the upper Madison basin to be known as the Hebgen Reservoir. This reservoir covers 13 450 acres and, with a dam 80 ft. high, will give a storage capacity of 13 000 000 000 cu. ft. The dam will be 80 ft. high, with a bottom width of 100 ft. and a top width of 400 ft. These plants, when extended to their full capacity, will yield 35 000 h. p. The power from these plants is transmitted under a pressure of 40 000 to 60 000 volts to Butte, Belgrade, Bozeman and Livingston.

The company's power plant on the Big Hole River is about 3 miles from Divide Station. The power development at this station is 4 000 h. p. and is delivered by mine to Butte.

Besides the dam and reservoir at the power plant, there is another dam and reservoir about 20 miles up the Big Hole River known as the Wise River Reservoir. This has a capacity of 450 000 000 cu. ft. of water. Another reservoir site is also available having a much larger capacity that will be built in the near future.

These various plants, as well as the reserve steam plant at Butte, are connected by a transmission line of 40 000 to 60 000 volts pressure and are so arranged that power from any one plant may be transferred to any other point in case of accident to any of the stations.

Railways.

Mr. William Ashton reports that the Oregon Short Line Railway has made practically no improvements on its line in Montana during the last year.

The Yellowstone Park Railroad, which is being constructed by the Oregon Short Line Railroad Company from St. Anthony

to the west entrance of the Yellowstone National Park, has been extended from Idaho into Montana over Rea's Pass, thence to the west, or Madison River, entrance of the Yellowstone National Park. About 9.8 miles of this railroad are in Montana. This line is now completed so far as track laying is concerned, and in shape for operation. We expect to do considerable Yellowstone Park business over this line. It is our intention next spring to arrange for passenger trains to leave Salt Lake in the evening and arrive at the west entrance of the Yellowstone National Park early the next morning. By this arrangement parties from Salt Lake and Ogden can make the trip to the Park, or returning from the Park, during the night. In constructing our line over Rea's Pass we used a 2 per cent. maximum gradient on the south side, 1 per cent. maximum on the north side. You will therefore note that in addition to the alignment over this pass being much more favorable than *via* Monida, the grades are considerably lighter.

For the Northern Pacific Railway, Mr. F. J. Taylor reports that they are building a new line along the Missoula River from St. Regis to Paradise, 22 miles in length, connecting the Cœur d'Alene branch with the main line.

Work is in progress on 25 miles of second main track over the Bridger Range between Livingston and Bozeman, and on 75 miles of second main track between Garrison and Missoula.

Besides the above, the principal work done has been on improvements and betterments of the main line, and considerable work has been done in enlarging engine facilities at division terminals and increasing shop facilities.

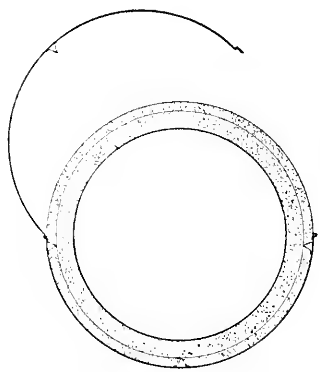
The Chicago, Milwaukee & St. Paul Railway has gone steadily on with its work till it is nearly through with construction. The track is laid from Harlowton east to a point on the divide between the Musselshell River and the Yellowstone River, about 140 miles east of Harlowton. Track is still being laid and will soon be completed to connect with the track from the east. The grading for the new track in Sixteen Mile Canyon is fully 80 per cent. completed. The piers for the Missouri River bridge at Lombard are completed and the bridge is on the way out from the factory. From Lombard to Butte the track is in a large part completed and the heavy work is well on its way. The line from Butte west is well under way, but I have not the data for much of a report on it.

The irrigation situation has been very quiet except for the work of the United States Reclamation Service. I have the

promise of a report on that from Mr. H. N. Savage which I will give to you in a separate report if it arrives as promised.

In making studies for a city water-works system I have been led to examine the merits of reinforced concrete pipe and will give you some of my conclusions. For the convenience of comparison and study I have assumed a pipe 12 in. inside diameter, 8 ft. long, with a working head of 150 ft., or 66 lb. static pressure. Any other size of pipe or pressure may be used on the same general principles.

A suggested method of making the pipe is as follows: The center form is of the usual collapsible style and 8 ft. long as being a convenient length. This is set on end in a pit 2 ft. deep prepared for it, with a cast-iron base placed in the bottom of the pit to receive the ends of the forms and to keep them concentric. The outside form is made in sections only 2 ft. long, so as to give easy access in ramming the concrete solid for the pipe. The sections are divided in the center lengthways with hinges on one side and clasps on the other, so that it may be opened. On the inside of the outer shell will be fastened four V-shaped pieces made of thin sheet steel, put in lengthways, three of them in what may be called the lower half when it is laid on its side, and one in the center of the upper half. These V-shaped pieces are notched at intervals of 1.5 in. and opposite each other so that the reinforcing rings may be spaced as required for strength. The rings will be set in the lower half at approved distances, and when the top half is shut down and fastened the reinforcing bands will be held solidly in place and 0.5 in. from the inner side of the form. This will give 0.5 in. of concrete outside of the reinforcing bands and so protect them from rusting. Wires for reinforcing the pipe longitudinally are introduced through the inside of the rings and wound around the ring nearest the end and spaced at equal distances. To start the construction of a pipe the inner shell is set vertically in the pit. The first section of the outer shell is placed over it at the bottom with the longitudinal wires projecting up and bent out a little over the edge of the section. The concrete is introduced and rammed solid. This ramming



Sectional View of Pipe and Form.

is the absolutely essential thing in making pipe, as on that depends the watertightness of the pipe. When the first section is complete the projecting wires are gathered to the center at the top of the inner shell and a small ring slipped over them. The second outer shell is placed and the longitudinal wires bent outward and the concrete introduced as before. When the last outer section is in place the longitudinal wires are cut to the proper length and twisted around the last ring at the end, and when it has been properly filled with concrete the whole pipe has been reinforced each way, all metal is completely covered in and there is no chance for rust. When two of the outer sections have been set, a movable circular platform, divided in the center and hinged, is drawn up and placed around the pipe, from which the balance of the work is done. When completed a light derrick lifts the form and sets it in the stock pile. When the pipe is ripe and the outer shell removed, the grooves left by the removal of the small forms that hold the rings in place should be filled and packed with a rich concrete and smoothed by a hand trowel.

The collars for the couplings of the pipes will be made similar to the pipe but larger and about 8 in. long. The joint packing will be of concrete, and driven hard with a hammer and calking iron.

As to the strength of concrete for making joints, I will say that last year I had occasion to build an inverted siphon over a new river channel on the Chicago, Milwaukee & St. Paul Railway work. Twenty-four inch heavy cast-iron water pipe was used with four 45-degree elbows to turn the pipe from the land level down to the bed of the river and back up again. The joints were all packed with concrete and held the water perfectly. Later a great flood came in the river and washed out the filling under one of the pipes and an elbow at one end. The 12-ft. length of pipe weighed 2 500 lb. and the 4-ft. elbow weighed 1 000 lb. The concrete in those two joints held that weight of 3 500 lb. for some months till it was convenient to fix it up. I should not hesitate to use concrete for joints in place of lead in even cast-iron water pipe.

The bands for reinforcing the pipe should be of mild steel of not less than 60 000 lb. tensile strength, and calculated for use at not more than 15 000 lb. per sq. in. The rods should be cut to the exact length, bent to the proper form and butt-welded with an electric welder. This will give a uniform size to the reinforcing hoops. Taking the assumed pressure of 66 lb. per sq. in., the

bursting pressure on 1 ft. of length would be 9 504 lb. As half of pressure applies to each side of the hoop, the pressure on one side would be 4 752 lb., and taking 1 in. of steel as 15 000 lb., it would require 0.32 sq. in. of steel to hold it with a factor of safety of 4, this on the supposition that the steel holds the entire bursting pressure. Dividing this amount of steel into 4 bands or placing them 3 in. apart from centers and making them 1 in. wide, the bands would be 0.08 in. thick.

The best authorities that I have give the tensile strength of concrete at from 200 to 600 lb. at thirty days set. Assume that we make a concrete of the strength of 400 lb. at thirty days. Then assume a shell of 1 in. thick inside of the bands, which is about as thin as I should want to go for strength and handling. Again our authorities say that the shearing strength of concrete is from 1.1 to 1.3 times the tensile strength. Suppose we take as our shear 1.2 times 400 lb., we have 480 lb. per sq. in. for the shearing strength. As our 1-in. bands are spaced 3 in. on centers, we have 2 in. between bands for the concrete to hold the strain. We are using 66 lb. per sq. in. pressure, and on the 2 in. there would be 132 lb. Now as the thickness of the pipe is so great compared with length of the section, and the compressive strength is so far in excess of its tensile strength, the concrete could not break by bending out, and the only way it could break would be by shearing between the bands. Again, if it should shear at all it would have to shear twice, that is, at each side next to the bands. We have then 2 in. of shear or 960 lb. of strength to hold the pressure on 2 sq. in., or 132 lb., or a factor of safety of 7. This does not take into account the 0.5 in. of concrete that I have placed on the outside for protection of the steel, which, though not as reliable as that inside the hoops, would still have a good deal of strength. Again, when the segment began to rupture by shearing, it would have to break across at least in one place and would give the added strength of the tensile strain, which we have taken at 400 lb. per sq. in. and on the 2 in. there would be 800 lb. of strength added. Altogether we should have nearly 1 000 lb. of strength to hold 132 lb. of strain on the concrete.

I have made these computations hurriedly and you had better check them carefully before using them.

In putting in a city system I should use cast-iron tees and crosses with all hub ends. For service cocks I should build as many into the pipes as there was any prospect of needing and locate them properly while laying the pipe. Afterwards if

others were needed I would use a cast-iron sleeve built in two parts to be placed around the pipe and edge-bolted, then pack with concrete and tap as you would cast-iron pipe. This system is unusually elastic, as you may make pipe of any size or strength. The place of manufacture should be at the most central point to the work, having regard to the convenience of assembling the material. Without searching for final prices, I figure that this pipe would cost about the same as the banded wooden pipe of the same strength, and not much more than half as much as standard cast-iron pipe would cost.

If the occasion for building a city water supply should materialize I should certainly recommend and urge the using of reinforced concrete for the pipes.

[NOTE.— Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by April 15, 1908, for publication in a subsequent number of the JOURNAL.]

THE SAN FRANCISCO EARTHQUAKE OF APRIL 18, 1906.

By Joseph H. Harper, Member of the Montana Society of Engineers.

[Read before the Society at its Twenty-first Annual Meeting, at Bozeman, Montana, January 11, 1908.]

Some six weeks after the San Francisco earthquake of April 18, 1906, I prepared an article, describing the impressions produced upon my own mind while the movements were in progress, together with a few interesting exaggerations as related by others who had a somewhat similar experience. The recounting and study of these personal impressions has always had a peculiar fascination for me, and reference to the article referred to will show how I was able to account for my own deception in a manner satisfactory to myself, but I often find it quite impossible to understand how the actual movements, as we now understand them, could have produced the fantastic impressions that have been left upon the minds of many.

A very large majority of those present have no clear conception with regard to the movements, and recall the incident as a confused succession of vibrations, jars and jolts that endured for a considerable period, while of those who did receive and can recall their impressions with regard to the amplitude or interval of the larger movements, I have yet to find two individuals, who were apparently similarly situated, who will tell the same story. Not only the physical environment, but the mental attitude of the individual, with the dim light or the absolute darkness in which many were enveloped, have doubtless all combined to deceive the senses and confuse the mind with regard to what was actually taking place. Every recital of these personal impressions but demonstrates anew the utter untrustworthiness of the unaided senses in estimating the amplitude of the movements involved.

One very naturally anticipates that a study of the movements of inanimate objects would throw some light upon the amplitude of the shocks delivered, and one with a larger experience might be able to obtain something of value on this point from the record of cracks and displacements that exist on every hand, but I must confess that my own efforts along this line have been somewhat disappointing.

I have spent many days in studying the effects of the earthquake and the fire upon the city of San Francisco, and in studying the effects of the earthquake at San José, Palo Alto and other towns about the bay, and in the cemeteries and country adjacent, and have made repeated visits to each of the places named, without being able to reach any definite conclusion regarding the amplitude of the larger movement, that which is described by many people as a rocking motion, and which is that portion of the quake that inflicted by far the greater part of the damage sustained.

I am forced to conclude that when the earth shocks become so severe as to cause vibrations far beyond the range of our ordinary experience, our senses fail in comprehension, and I feel that no accurate knowledge of the actual maximum can be obtained except from the record of instruments constructed for the purpose, and further that a seismographic record will not be a reliable index of the actual movements except for a very restricted area about the locality in which it is placed. As reliable instruments of this character are somewhat expensive and when maintained in perpetual order require considerable technical attention, and the number established in any particular locality is naturally limited, we should not be surprised to learn that but few were found within the area seriously affected, and none, I am told, were situated in San Francisco.

Without doubt much can be learned by comparing the data available from other stations and when the commission which is now investigating this entire subject has made its report, I think we may learn something regarding the maximum movements within the area of greatest disturbance.

These remarks, so disparaging to all personal estimates, and the doubts I have expressed about my ability to place a definite value upon the movements, apply only to the amplitude of the heavier shocks and do not apply to their frequency, nor do they apply to either the amplitude or the frequency of the lighter vibrations that endured for a much longer period and constituted a large part of the disturbance. These lighter movements could be fairly understood by those who were awake at the time, their amplitude estimated with some degree of assurance, and the frequency of all could be counted, quite closely I should think, by those who are accustomed to rating mechanical movements.

Before going further I will relate more carefully than I have heretofore done my experience during the quake and give the results of my personal observations during that time, eliminating

therefrom, as far as possible, those features in which I can now recognize that my senses were much confused, and that through them I was greatly deceived.

Within an hour or two after the occurrence I was asked for an estimate of its duration. I was about to reply one minute, when that time seemed rather long and my answer was 50 seconds. At the time many were estimating it at 5 and some even at as much as 10 minutes. I now think that I missed something in the earlier stages, and that from the first to the tenth second was really a longer interval than I then thought it. There is a chance for some discrepancy in determining the end of the movement, as the vibrations died out very gradually and may have continued longer than a person whose attention was seriously engaged would notice them. There were a number of lighter shocks during the day, but after the one of the early morning they attracted but little attention, and these continued, separated by irregular and increasing intervals that extended from minutes to hours and days, for many weeks before they finally ceased.

Assuming, then, 50 seconds to be a correct measure of its duration from the first warning note to the last perceptible vibration, and using this as a basis, I will subdivide the period, designating the interval by the numbers of the second elapsing as counted from the first warning note.

The prelude, or opening, was a very low rumbling noise like distant thunder, or an ore car far away in a mining drift, which began at the first second and gradually increased and became more distinct until about the fifth, the sound gradually growing in volume much as it does when a train approaches one through a tunnel. During this five-second interval there was no movement that attracted my attention, and I attributed the sound to some machine in the basement running at an unusual speed.

At the fifth second a vicious intermittent jolting movement began, and in mp estimation continued without cessation at any time to the fiftieth second or the end of the quake. This motion appeared to be mainly in a vertical direction, with an amplitude ranging from $\frac{1}{8}$ in. to $\frac{3}{8}$ in., and moved with a frequency of about 240 per minute, or about 4 cycles per second. These vibrations seemed to rise in pulsations and die down, to be renewed with greater violence at intervals ranging from 2 to 4 seconds each, this change apparently being accomplished by a variation in their altitude rather than by any change in their frequency. These movements were forceful enough to make

everything loose dance and chatter continuously, they were accompanied by a considerable volume of sound, though they did not rock the building very severely, and finally died away in falling pulsations by a reversal of the manner in which they had arisen. I believe this movement to have been continuous in some degree for the entire 45 seconds, for the reason that, between the intervals of the more violent oscillating movements, which I will soon describe, the rattling of the chandelier fixtures, the windows and the chattering of some loose objects on the marble-top dresser due to this movement, could be distinctly heard, just as both before and after the heavier shocks.

At about the tenth second there came a crash as of something shattered, and the falling of the broken parts.

I shall probably never know what caused the crash; my first thought was that the elevator had been run into the sheaves, but a moment later, realizing that an earthquake was upon us, I raised myself to a sitting posture, and was certainly wide-awake from this time on, though I made no further move till all had passed and everything was again quiet.

I have some misgivings with regard to the preceding time intervals as I have given them, but from this moment on I can speak with more assurance.

The vertical vibratory movements I have just described were at this time in full swing and increasing in amplitude and violence at almost every rising pulsation. These shocks, though more violent, did not differ greatly from some I had before experienced, and had this been all might have endured for a full minute and passed without doing any great amount of damage. But this was not all.

From the twentieth to the twenty-sixth second, for an interval of about 6 seconds, there appeared a violent reciprocating movement of tremendous energy, much stronger in its horizontal than in its vertical component, having an interval of about 90 per minute or 1.5 cycles per second, which was superimposed upon the lighter vibrations and while in progress wholly dominated all other movements. An exhibit that aptly illustrates my idea of the manner in which these different vibrations are imposed upon one another may be seen by observing the ripples that always play over the surface of the larger waves when the water is rough.

These heavier shocks were not of constant energy but seemed to progress in three distinct pulsations, each separated by an interval of comparative quiet, the change, as was noted with

regard to the lighter vibrations, being effected by a variation in amplitude rather than in the frequency of the movements. For the first three or four shocks the motion appeared to be in a general easterly and westerly direction; then, after a pause of a moment or so, two or three somewhat lighter occurred with an apparent motion nearly north and south; when, after another pause of a second or two, and another change in direction, some three or four additional shocks, the first of which seemed more violent than any of the preceding, were delivered in an easterly and westerly direction; when these in turn died away and disappeared among the lighter movements that I think had been in progress all the time, and that continued to the end of the disturbance.

Words fail utterly when I attempt to convey an adequate idea of the dynamic energy manifested in each of these larger movements, as they appeared vicious in the extreme, and forceful to a degree far beyond anything I had ever experienced or imagined as possible. The blows were delivered as intense, instantaneous and resistless shocks, of startling severity and limitless power, crushing everything that offered sufficient resistance, and rending and tearing everything that did not bend to their requirements. The building rocked and swayed in an alarming way, while at every lurch there came the sound of groaning timber, the creaking of nails and spikes being drawn, the snapping of painted woodwork, all of which, when joined by the rattle and jar of everything loose, filled the room with a confused din that was disconcerting in the highest degree.

For reasons heretofore given, I cannot estimate the amplitude of these larger movements with any degree of assurance, but I cannot see how the effects produced by them in my immediate neighborhood could be accomplished without an actual movement of at least 2 inches, and indeed for some of the exhibits it would seem that considerably more than this would be required.

You will understand that what I have written has special reference to what occurred in our own apartments, that is, on the fifth floor of a very well-constructed frame building standing on a good brick foundation at 808 Bush Street, but I imagine it will fairly describe the experience of a large majority of those who were similarly situated about the city of San Francisco.

In estimating the magnitude and intensity of the movements in any locality, one must depend largely upon the character of the effects they produced, and these when found are generally

more or less illusive, and very unfortunately are often quite contradictory.

The lighter shocks, those whose main component was vertical, I imagine were substantially the same in all parts of the city and were but slightly modified at elevations above the ground, while with the larger or horizontal movement a marked difference seems apparent between different points in the same locality, and I feel quite certain they were often greatly magnified, or much modified, dependent upon the character of the structure in which the observer was situated and his elevation above the ground. Generally they appeared to be amplified in some degree on the upper floors of most buildings, but it does not follow that the higher the floor the larger they became, for if the building were tall enough, one or more nodes would usually appear in the vibrations, which must greatly modify the character of the movements.

The point where the reversal took place was made manifest by the shattering of a story or two, while at other points the walls would escape comparative injury. There were so many buildings to be seen about the city with one story, usually between the fourth and eighth, badly damaged, while those above and below were apparently unharmed, that this feature became quite noticeable. It is generally believed that the shocks were much more severe on what is known as made ground, or land that has been reclaimed by filling in along the water front, than they were in sections where a rock foundation was obtainable. It is true many buildings on an elastic foundation suffered severely, but it is also quite true that many frail structures so situated were marvelously preserved. My impression is that the most intense shocks were delivered from the firmest foundations and to the buildings most rigidly constructed, and while the amplitude of the movement may have been greater where a more elastic foundation or method of construction prevailed, I think the shocks lacked something of the dynamic energy that is evinced where the foundations were more solid or the structure less elastic.

Volumes might be written descriptive of the havoc wrought by this terrible visitation which in a few moments wrecked the city and started the fires which eventually destroyed it, shattered the nerves of a large majority of its population and profoundly impressed all by a momentary exhibition of limitless power, but I have time only to note a few cases which occur to me as most interesting.

One is early impressed by the abundant evidence of the most erratic damages, and still more unaccountable immunities, that are exhibited side by side on every hand. In our own apartments (on the fifth and upper floor) the motion was certainly severe, as a steam radiator that naturally stood 2.5 inches from the wall was thrown over until it inclined at an angle of 25 degrees from a perpendicular, though the iron fittings by which it was connected were so ridged that I found it impossible to replace it unassisted, and yet in these rooms nothing of moment was broken and no other furnishing was seriously disturbed, while in the rooms next below nearly everything movable was overturned, many objects were broken and much damage done. Mrs. Harper explained this by saying that in our rooms almost everything stood out from the side walls while in the rooms below many of the furnishings were set close against them, and in this remark I have found an explanation for much apparently fitful and capricious destruction noticed in all parts of the city. In the simple conditions here presented, with the results observed, will be found a key that will explain the collapse of the City Hall, the destruction of much property in San Francisco and the fall of many buildings at Palo Alto, Agnews, San José and other points about the bay.

The lesson to be drawn, and to which I shall again refer, when briefly stated, is that objects must be separated by an interval so great that they will not collide, or they must be bound together so they will move as one. Marble-topped furniture, tables in particular, seemed to be marked for destruction, and they were, literally by the hundred, fired from the walls across the apartment and were very frequently disfigured or broken. The fire mantels and marble wainscoting were interior decoration for the destruction of which the shocks appeared to have a peculiar *penchant*, and when we recall the manner in which these fittings are usually fastened, it is easy to understand how the first movement might separate them from the wall and the second send them shattered and broken far into the room. In like manner a plastered surface, if at all loose, would be easily broken and thrown into the room, but I think firm walls of good mortar usually came through without serious damage. Though I have noticed many marvelous escapes, bric-à-brac was usually scattered in wild confusion, small flat objects were often completely overturned, pictures were thrown down, while the spectacle of one, though two or more feet across, with its face turned to the wall, was not an unusual occurrence.

I have found the cemeteries a fruitful field for the study of eccentric movements. In Laurel Hill I noted two similar granite shafts, separated by less than 200 feet, one of which had been turned to the right upon its base some 15 to 20 degrees, while the other, upon the same style of a foundation, had been turned as far to the left.

Among many of like character I noted a monument, with pedestal, shaft and capital, in which the shaft had turned in one direction upon the pedestal, while the capital had turned in the opposite direction upon the shaft on which it rested to a much greater extent, and both movements were attended with an adverse lateral motion of the members.

There is no apparent regularity in the direction in which the upper stones have moved upon the lower. A northwesterly and southeasterly direction may be most frequent, but I have noted these movements toward every point of the compass. There was nothing in the movement that gave me an impression that it was rotating, but a number of witnesses have stated that among the other movements they detected a circular or twisting tendency. I think the tendency to rotate is the resultant of two or more components from the other movements, and the manner in which they were combined in any particular locality probably determined the direction in which the object affected would turn. There remains, however, a difficulty in understanding how a capital can turn in one direction while the shaft upon which it rests is turning in the opposite direction upon its foundation.

The most perfect illustration of this tendency to rotate which I have anywhere noted was seen in a brick chimney about 2 feet in height, and the only one that I could see standing in that locality, which had made a quarter turn to the right by the movement of each individual brick upon the one on which it rested, with their final arrangement almost as perfect as could have been secured had a mechanic been employed to place them there.

Though I believe a measurement of the horizontal component of the earth's movement would greatly exceed any instrumental record that I have ever heard mentioned, there are many tall, slender and apparently unstable objects about the city that still stand erect and uninjured.

In spite of their amplitude and complexity it is still possible that a person standing upon one foot in the middle of a room would have felt the movements less than one who had a larger surface in contact with the floor, as in the end, without question,

the sum of them all practically balanced one another, and the ultimate motion, if there were any, was probably small and the new position gradually attained.

I note three familiar objects that illustrate this feature, one being the Dewey monument in Union Square; the second, the Native Sons monument at the entrance of Mason and Turk into Market Street; and the third, two columns which many will remember at the southwest corner of the City Hall, at the intersection of Grove and Larkin streets, which stood for many months capped across by a section of the architrave which originally rested upon them. The two objects last named both illustrate the universal character of the movement, as the projecting cove at the base of the Native Sons shaft had been spalled and broken off quite impartially in all directions, while the ornamental castings at the base of the City Hall columns had been broken on all sides.

Further curious and interesting effects of the fire and earthquake might be described, as they are in evidence on every hand, but features of more practical value to the engineer and structural artisan relate to the character of material and methods of construction that can best withstand a constant war with the elements and an occasional assault of earthquake, fire or flood.

It is now apparent that, from the moment of the shock, which occurred at 5.15 A.M., the destruction by fire of a large portion of the business section of the city was foreordained, for before leaving my room at about six o'clock I had noted four separate and distinct fires, and there were really six, I have since been told, all of which looked threatening in the extreme and were apparently at that time beyond control.

I am not equipped to discuss in a technical manner the stresses and strains involved, or the size and proportion of members required to secure stability in large municipal structures of recent years, as my practice has usually lain along other lines of work, but my experience in San Francisco, and my observations since, have developed a few persistent notions of what it is desirable to attain, and some regarding the conditions it is necessary to avoid in buildings designed to stand the shocks of an earthquake and endure the fires that may follow.

There are two properties in available building material, rigidity and elasticity, that we may invoke, and these may be employed to produce two very dissimilar structures, either of which will sustain shocks without injury, but the ideal building will result from a judicious combination of the two rather than

from the exclusive use of either. A granite block and a rubber globe will both endure the roughest usage without injury, but the first accomplishes the result almost wholly by transmission, while the latter largely absorbs the force of the blow.

To build strong enough is a solution of our difficulties in but one direction, for not only should the structure stand, but it should possess a property that will absorb the energy, modify the movements and thus in some measure protect the occupant and the interior furnishing. In small buildings elasticity is of comparatively slight importance, and in all timber work is naturally attained without special effort, but in larger structures, and particularly in all tall buildings where this property seems most desirable, the best results cannot be secured unless careful provision therefor be made in the design. A large part of the immunity from damage observed in wooden buildings is doubtless due to their inherent elasticity, and to the fact that many of them were placed upon a frame underpinning from 2 to 4 ft. in height, usually lightly inclosed and often left entirely open. This style of foundation is much in vogue in California, and in San José, where the quake was probably stronger than in San Francisco, and where I saw many such buildings, I cannot recall one that had sound walls and was well built that sustained any serious damage unless the foundation had failed, and in that case they were without exception very badly wrecked.

For tall buildings the modern steel frame is the only style of structure to be considered, and in the San Francisco test they gave a very excellent account of themselves.

As usually designed the attachment between the posts and girders appears weak, and the bracing between all vertical and horizontal members entirely insufficient to safely withstand the burden of a shock, but I have a suspicion that the large riveted corner plates and the rigid diagonal bracing now being used on some of the buildings under construction is a departure on the opposite extreme.

Much is claimed for "reinforced concrete," and if concrete be properly reinforced it is without question a most excellent material, combining in a marked degree the desirable properties of strength and elasticity, but I cannot avoid an impression that this material is just now being badly overworked. Concrete in dams, bridges, retaining walls, foundations and all sub-work fills an important field, and in recent years its intelligent reinforcement has enabled us to economize greatly in quantity and to use it for many purposes for which it is not otherwise suitable,

but I do not feel that any method of reinforcement that I have yet seen will render it a desirable material for the construction of supporting members in buildings that are more than four, certainly not more than six, stories in height.

Concrete construction is usually monolithic in character, and in this respect is admirably adapted to withstand earth shocks, but one naturally speculates on what might occur if an important vertical, say one of the lower columns, should cleave on a plane approaching a diagonal through the member. With a rupture of this character we could hardly expect the reinforcement to carry the entire shear strain, and a very serious situation is presented.

A column of brick similarly situated would possess the virtue of falling slowly; it would disintegrate on a series of vertical and horizontal planes, and will usually carry its burden for a considerable time though badly shattered.

The argument that concrete is cheaper and can be placed in position with ordinary labor has largely disappeared when it is used in forming the important members of a large building, for in addition to generous reinforcement, the best of selected material must be used and a care in every detail of construction realized that cannot be attained without employment of men with large experience and special training in such work.

But poor material cannot be held responsible for anywhere near all of the failures that occurred in and about San Francisco, for poor workmanship was responsible for many, and a radical defect in the design directly responsible for some of the most lamentable. A heavy dome upon a light skeleton of steel, projecting far above the body of a building, unless securely bound thereto by a substantial and elaborate system of bracing, is a form of architecture that simply courts disaster. The imposing City Hall in San Francisco and the barely completed gymnasium at Stanford were both examples of this character, and both were seemingly wrecked much in the same manner, by battering themselves down through unequal vibrations between the buildings and their respective towers. The assertion is frequently made that the material used in the City Hall and the buildings at Stanford was very poor, a remark that caused me to examine the work with more than usual care. The material is well above the average in grade; most of the mortar used was of good quality, some in fact very excellent; and I found none worth noting at either point that was positively poor.

One would naturally anticipate that in a region where earth-

shocks were not infrequent special care would be taken to bond all work securely, but here a different policy seemed to have prevailed, for I have never seen as much poorly bonded work, nor such a quantity of work without even a pretense of bonding, as was exposed in San José and Palo Alto, and in general about the city and bay of San Francisco.

A style of construction much in vogue with the architects here, and used extensively upon many large buildings, consisted of a veneer or facing of dressed stone backed by a wall of brick, concrete or rubble work, but instead of being thoroughly bound together, the two courses were often continued for a story or more without the use of a single tie that I was able to discover, while what in mason work is termed a "header" was apparently unknown.

Much damage resulted from overturned chimneys, the falling of cornice and other ornamental members and the throwing of firewalls upon adjoining property, but danger from this source will be very greatly reduced on the buildings now going up, for as reconstruction proceeds one can note many provisions for supporting and anchoring these ornamental projections that were formerly regarded as unnecessary,

After many large fires, engineers and architects have often found it difficult to determine what proportion of the damage done to stonework should be attributed to the fire and how much to the water that was used, but in San Francisco abundant opportunity has been offered to study the effects of fire without water upon structural material, and in my judgment the use of water can add but little to the destructive effects of a great conflagration.

As in Baltimore, Chicago and other severe fire tests, so in San Francisco, the common, ordinary brick of good quality, I think, comes through with a far better record than was made by any other material in general use. The opportunities for observing it after a fire test were not as numerous as one would expect, owing to the abnormal proportion of wood that entered into the construction of the city, and owing again to the indifferent character of both brick and mortar so frequently used, which failed to support the walls after the floors and tie beams had been burned away. There were, however, a few large and well-built brick buildings in the city, and so far as my observation goes, every wall of good common brick well laid in cement mortar stood through both the earthquake and the fire without serious damage. The walls of St. Francis Church, at the intersection of

Montgomery Avenue and Vallejo Street, stand to-day without a serious crack and with the brick work but slightly damaged, while their sandstone foundations have spalled to an average depth of about 5 inches.

St. Mary's Church, at the corner of California and Dupont streets, stands with the main walls uninjured, though the rear gable that presented a large unsupported surface has fallen. The Jewish synagogue on Sutter between Powell and Stockton streets was reconstructed before I had an opportunity to examine critically, but I have been informed was well preserved. True, these walls are all heavier than it is practical to use in ordinary buildings, and this feature may have contributed in some degree to their preservation, but I think the secret lies rather in the quality of the mortar used and the character of the bond employed to bind the brick into a homogeneous whole that will vibrate *en masse* without rupture. The Appraisers' Building, corner of Washington and Sansom streets, and a number of smaller buildings that I cannot now locate, are examples of lighter walls that came through the quake in fine form but escaped without a serious fire test.

A wall of good brick well laid in good cement mortar will, I think, be quite as, if not more, elastic than one of concrete, while it will head the list for endurance under fire. The fire-resisting properties of concrete are also excellent, though it does not come through wholly without damage. If the test be severe enough, the life seems to be burned from the outer surface, and this portion will disintegrate easily, to a depth depending upon the fierceness of the fire and the duration of the test.

I regard brick as the best all-around structural material we yet possess, while concrete follows as a close second, in both elastic and fire-resisting properties.

Stone of every character failed, marble most signally perhaps, but granite, lime and sandstone all spalled off badly under the heat, and several buildings, otherwise uninjured, were so badly defaced that their practical reconstruction is a necessity.

Damage from this cause alone was really very great, as it was almost universal, and at some points the chipping was very deep, one instance noted being the north end of the Shreves Building, corner of Post and Grant streets, where the alley was literally covered with spalls, and some pieces having a superficial area of 10 or 12 inches were thrown a distance of 60 feet from the face of the building.

A variety of terra cotta finishings, and nearly all of the

unglazed tile in use, passed the fire test in good form, but all hollow work of this character suffered severely from the shock, and though an utter failure was rare, partial failures were very numerous and its general performance tends to discourage its further use in all positions where much weight is to be carried and in all localities where earth-shocks are to be apprehended. A large assortment of fancy and pressed bricks were in use, nearly all of which made an excellent record, but the glazed or vitrified varieties were often spalled and chipped at the corners and along the edges from the effects of the shock.

To build stronger than your neighbor is a safe proposition unless he is entertaining the same idea, but the spirit is too selfish to be taken seriously. The necessity, however, of paying some attention to what is being done on adjoining property was abundantly manifest at San José and other towns as well as in the city, for the crushing of a low or weak front, or the forcing of it into the street, by the pressure of taller or stronger structures on each side, was a manner of failure very frequently observed, while on the other hand, if the lower building was substantial enough to hold its own, the taller structure would be badly damaged in that portion projecting above the general level.

The conditions above named, with the inherent elements of weakness in conspicuous evidence, are so frequently encountered in all business districts that I would like to suggest some easy way of avoiding trouble, but the only efficient method that occurs to me is to leave a small open space between the buildings, and this plan, I presume, will generally be rejected. A small space, an inch or less, would generally be sufficient, and there are many ways in which it could be covered and made to appear respectable.

Much damage was accomplished by the thrust of rafters and truss members that threw the top of side walls out and caused them to fall. It seems hardly necessary to suggest that an effectual remedy for this consists in strengthening the chords and securing them at the foot of the trusses in a manner that they may sustain any thrust that may come upon them, thus making the truss a substantial tie and an element of strength instead of weakness.

The ideas suggested by the observations I have made, the more interesting of which I have endeavored to describe, may be summarized in the following half-dozen hints, which, if duly regarded in the work of rebuilding, will materially reduce the damage sustained should earth-shocks of like nature again occur.

First: Seek a solid foundation and thus insure against the

vibrations of the ground being amplified in the structure should its movements be any synchronous multiple of those made by the earth.

Second: Use the best material of its kind obtainable, and insist that it be assembled in a substantial and workmanlike manner.

Third: The walls and all members should be homogeneous if practical, and when this is not possible and different materials, as steel, stone, brick or concrete must be joined, see that they are bound together and will move as one.

Fourth: Every structure should be treated as a unit, and all members and every part thereof should be tied to insure its movement in unison; there must be no separation, none whatever.

Fifth: Avoid projections as far as possible, but when necessary, as in cornice and ornaments, furnish ample support and tie securely to the main building; avoid members that project above the general level, but when unavoidable, as chimneys and firewalls, brace firmly to the body of the work.

Sixth: Limit the height of buildings to what in other localities would be regarded as a modest elevation for one of its class, leave an open space between buildings on adjoining property and in general remember that between buildings, or between the different members of a building, or between the fittings within the buildings, or between different objects anywhere, collisions must be avoided, for in the impact of collision the work of destruction has both a beginning and an end.

[NOTE.— Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by April 15, 1908, for publication in a subsequent number of the JOURNAL.]

RECLAMATION PROJECTS IN MONTANA.

By H. N. Savage.

[Read before the Montana Society of Engineers at its Twenty-first Annual Meeting, at Bozeman, Montana, January 11, 1908.]

Huntley Project.

The lands under the Huntley Project are situated in the Yellowstone Valley and extend in a compact body from Huntley to Bull Mountain Station on the Northern Pacific Railway. The lands, which comprise an irrigable area of about 33 000 acres, are all on the south side of the Yellowstone River and are crossed by the Northern Pacific Railway and the Chicago, Burlington & Quincy Railway. The irrigable lands slope gently toward the Yellowstone River. They are in general smooth, and there will be but little expense in putting them under irrigation. The Farm Unit consists of 40 acres of irrigable land, with which is included such pasture land or woodland as could be found adjacent. The farms will, therefore, contain 40 to 160 acres of land, of which 40 or more acres will be classed as irrigable.

The Main Canal, which has a total length of 23.5 miles, is taken out at the bottom level of the Yellowstone River about 2.5 miles west of Huntley. The canal diverts at normal capacity about 400 second-feet of water from the Yellowstone River. The Main Canal for a distance of 2.2 miles is located along the Huntley Bluffs. The headworks consist of a reinforced concrete structure provided with two steel gates 5 ft. by 7 ft., and arranged to divert water without the necessity for a weir. From the headworks the water is carried through Tunnel No. 1, which is 700 ft. long, and thence through a rock cut to Tunnel No. 2, which is 1 500 ft. long. From Tunnel No. 2 the water flows through an open slough and into Tunnel No. 3, about 400 ft. long. The three tunnels have a total length of 2 650 ft., are 9.2 ft. wide and 9 ft. high at the center of the arch. They are lined with concrete, and at the entrance of Tunnel No. 3 there is a heavy reinforced concrete wasteway, which at low water will discharge under the tracks of the Northern Pacific Railway into the Yellowstone River. All structures such as culverts, siphons, etc., are of a permanent type. The building of these structures, which was completed June 1, 1907, included the placing of 3 500 cu. yd. of

concrete, the greater percentage of this being of the reinforced type.

In making the location of the Main Canal, two drops were necessary, the first about a mile east of Ballantine and the second about 4 miles farther. At the first drop a pumping plant has been installed to pump water to the Ballantine bench and the lands along Fly Creek. The Main Canal at this point will carry about 240 cu. ft. of water per second, which will be dropped about 34 ft. and will develop power sufficient to raise about 56 cu. ft. of water per second to a point 45.5 ft. above the Main Canal where it will be discharged into the High Line Canal. The machinery for this plant reached Ballantine early in July and is now installed. The concrete power house and the concrete pipes in connection therewith have been completed by force account, it having been found impossible to obtain reasonable bids. The machinery is of novel design and has been built especially for this plant.

At the second drop, the water is carried down through a concrete pipe about 800 ft. long, and discharged into a diffusion chamber which is provided with a wasteway. At present no use is contemplated for the power which could be developed at this point.

Water was available for the irrigation of the land on the Huntley Project in the fall of 1907.

Sun River Project, Montana.

Sun River Project is located to the west of Great Falls. The irrigable area, 264 000 acres, lies between the Sun River on the south, the Teton on the north, the Missouri on the east and the Rocky Mountains on the west. Additional area was examined during the season of 1903. During the season of 1904 surveys were extended to include the storage dam and diverting weir sites. The diverting weir site is in a canyon where the river bed is only 54 ft. wide. The weir will have a height of 72 ft. and a top length of 170 ft. Solid limestone rock extends entirely across the canyon, and there is no doubt as to the character of the foundation.

At the weir the north side diversion line starts into a tunnel, the first 1 000 ft. being through very solid limestone. From this point to Station 50 the tunnel was continued in preference to open cut because the steep hillside character of the country makes the former the cheaper, the location being carried far enough into the hill to get secure ground and cheapen the cost of con-

struction. This line has been located throughout the entire distance to Pishkun Reservoir, 13.6 miles, and while it extends through an apparently difficult country, is very satisfactory. Pishkun Reservoir has a total capacity of 45 747 acre-feet if carried to Elevation 4 370.

The Freez-Out Bench Line heads in the Pishkun Reservoir and extends eastward 23.5 miles to where it drops into Spring Coulee. The first 6.5 miles runs through a rolling glacial country; then the line is started along hillsides to reach the bench level at Station 480. In its entire length there will be two tunnels through glacial gravel. The first will have a length of 2 200 ft., and the second a length of 2 000 ft. After passing through the outlet tunnel of the Pishkun Reservoir the water for the Teton slope will run down a coulee into Deep Creek, and down this to the diversion weir, a total of 12.5 miles through natural channels. The weir as planned will be of concrete, 12 ft. high and 100 ft. long, with a 500-ft. earth embankment on the west side to confine the water to the channel. The distributing canal starts on the east side of the creek at the weir, and after the first 0.5 mile begins to serve the bottom lands along the creek, gradually drawing away to the southward.

During the past season work has been confined to the Willow Creek Dam and the Fort Shaw end. Work on Willow Creek Dam was closed down the first week in October and the equipment transferred to Fort Shaw work. Excessive snows during the winter of 1906–7, followed by a cool wet summer, insure ample water in the river for probable demands for several years. The work at this point has been as follows: Shaft sunk and timbered, 66 ft. complete ready for concrete and valve; tunnel driven and timbered, 584 ft. complete; conduit concreted, 600 ft. complete except connections for lower portal and shaft.

Work on the five divisions of the Fort Shaw canals has progressed satisfactorily with the exception of Division 3. It is expected that work on the structures of Schedule B will be completed by the end of the year. At Sims Creek Siphon, temporary office, mess house and two bunk houses have been completed. Steel and cement are on hand, and piers to support the pipe have been begun. The barrel of the pipe has been begun and it is expected that it will be completed by the end of December.

The Concrete Factory has been maintained and the pipe distributed along the canal and the culverts built ahead of the requirements of the contractors. The Canal System for the Fort Shaw Unit will be completed and water will be available for the irrigation of 16 000 acres by June 1, 1908.

Lower Yellowstone Project, Montana.

This project is located on the Yellowstone, the canal heading on the west or left bank of the river about 20 miles below Glendive and about 2 miles below the mouth of Thirteen Mile Creek. The survey was begun in August, 1903. The results show that a canal 67 miles in length will serve 70 000 acres.

Yellowstone River from the point of diversion to its mouth has an average fall of 2.2 ft. per mile. Much of the land to be irrigated by this system lies in benches 90 ft. above the river, and in order to reach it with the canal it is necessary to raise the water in the river at the head gates by means of a diversion dam and to build the canal on as low a grade as possible.

On the canal side of the proposed diversion dam the bank rises 50 ft. above the water surface of the river. On the opposite side, however, the bank is low, being but 15 ft. above low water and extending back for about 2 miles to high bluffs. The dam will be of the rock-filled timber crib type. The borings show that the river bed is a hard stiff clay for a depth of at least 50 ft. This material is excellent for holding piles. Several rows of piles will be driven across the river and the spaces filled in with large stone. The face will be covered with timber, having a slope of 3 to 1 on the up-stream side and a slope of 6 to 1 on the down-stream side.

The canal will have a capacity of 850 second-feet and a grade of 1 in 10 000. In order to obtain as great a velocity as possible with this low grade, the canal is built narrow and deep. By doing this a velocity of 2.1 ft. per second is obtained. About 25 miles of the canal is through very rough country and the work is exceedingly heavy. There are 13 difficult creek crossings, one of which is made with a double barrel pressure pipe 300 ft. long and 9 ft. in diameter. With the exception of a few hundred yards, the material excavated from the canal is all earth.

The construction work on this project is drawing rapidly to completion. The engineering work has been carried forward to keep pace with the requirements, and the organization of the Water Users Association has been perfected. The contractors are continuing to get lumber from the coast and are hauling stone from the quarry to the dam site in order that all of the material may be on the ground so that they may begin operations as soon as the ice goes out in the spring of 1908. During the past three months progress has been slow, but it is hoped that the work will be about 70 per cent. complete at the end of the calendar year.

All work will be completed and water turned into canal in the fall of 1908.

St. Mary Project, Montana.

St. Mary Project is situated in northwestern Montana. The general scheme is divided into two parts: storage of the flood waters of St. Mary River and the diversion of this water into the headwaters of the Milk River, and the utilization of the water on the irrigable lands of the lower Milk River Valley.

It is proposed to store the flood waters of St. Mary River by constructing an earthen dam at the outlet of lower St. Mary Lake. This dam, which will have side slopes of 3 to 1, a top width of 20 ft., will be 2 800 ft. long and have an effective height of 31 ft. This will give a reservoir capacity of 150 000 acre-ft.

The canal for conducting the water from St. Mary Reservoir to the north fork of Milk River will have a total length of 25 miles. The first 6 miles will be along the canyon of the St. Mary River, and about one half will be lined with concrete. The remainder is along the rolling foot hills where the construction is easy. From this point the water will be allowed to flow down Milk River through Canada and back into Montana. The water will be used to irrigate about 250 000 acres of land lying along the Great Northern Railway east of Chinook.

During the season of 1907 construction work has been carried on by force account. A 65-ton steam shovel with 2.5 cu. yd. dipper has been at work all summer near the upper end of the canal. A steam excavator with 2.5 cu. yd. dipper was placed on the lower division and continued work until the middle of October. Construction work has been suspended on this project for the winter.

[Note.— Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by April 15, 1908, for publication in a subsequent number of the Journal.]

ANNUAL ADDRESS.

By George W. Lawes, President of the Louisiana Engineering Society.

[Read before the Society, January 10, 1908.]

Mr. President and Members of the Louisiana Engineering Society: At this, the end of my official term as president of this society, I am, by mandate of the constitution and by-laws, compelled to address you. I will not take up much of your time, as, with the other business of the meeting, much has already been monopolized, and we are all impatient, I know, to see what our good friend Mr. Eastwood has in store for us in the banquet hall.

It is well, however, on this, the tenth anniversary of our existence as a society, to look back over the path we have come and see if, between the markings of the milestones, there may not be interesting things to contemplate: Things which may point out to us where we have been wise, and others which may show where we might have been wiser; and also it will be well, as we enter upon our second decade, to make plans for our future upbuilding and greater success.

In January, 1898, the charter of this society was taken out by twenty-four engineers. During the first year the membership was increased by twenty-six members, or over 100 per cent. Since then the membership has grown steadily, until to-day over one hundred members are on the roll, and amongst this membership are most of the engineers of high standing in this city and state. From 1898 to 1902 the society prospered. Interest in its affairs was taken by the members, the finances were in good shape, attendance at meetings was large and the papers presented were discussed thoroughly and interestedly. Three outings were taken, which were successful in point of attendance, and novel as to places visited, but, except the first outing of the society to the drainage plant of this city, all have been a drain on the society's treasury and have been taken at a loss financially. From 1902 to 1905 the finances of the society were at a low ebb, owing to the excessive cost of the outings, and it was a struggle to keep things going. During this period, notwithstanding the different administrations worked as hard and prepared interesting programs for the meetings, the attendance at meetings began to fall off, and has continued to.

Since 1905 the finances have improved, the stringency in our money market has been broken and we have a comfortable surplus on hand, notwithstanding an outing taken this year which cost the society $4.40.

From 1898 to date we have added largely to our library in the matter of bound volumes of engineering periodicals to which we subscribe; a few books have been donated and several technical works purchased. Except our bookcases, which are as good as new, our furniture has dwindled to a library table and the secretary's desk, and this, the secretary says, needs repairs.

In the matter of work done by the society, I think we can feel satisfied. Very few meetings have been held at which a paper of interest has not been presented, and several of the papers have attracted the attention of engineers and the technical press throughout this country and abroad.

So altogether I think we can slap each other on the back and say, "Good for the Louisiana Engineering Society!"

We want, though, at the end of the next ten years, to be able to reach, if not Excelsior, at least to show a marked advance over the ten years past. And we want to consider seriously in what way this can be accomplished. One of the first essentials, to my mind, is that each and every member must take an absorbing interest in the welfare and advancement of the organization. Without this no organization will progress. The officers may be the best, their administrative work be perfect, their efforts to secure interesting programs successful, — all will be for naught if the members do not take interest enough in the society to attend the meetings and by the magnetism of their presence instill life and spirit into the proceedings. Exceptional papers cannot be supplied for every meeting, but as a rule no member prepares a paper that he does not put forward his best effort, and whether he is successful in interesting or not, he should be made to feel that the effort is appreciated for the will if not the deed. It is very discouraging, after careful preparation of a paper, to read it to empty chairs, and the member going to the trouble to prepare a paper deserves better treatment. Come to the meetings whether you are interested in the subject or not; come because of your interest in the society, because you belong to it, are proud of it and want to aid in its progress.

The business of the society can be carried on by a bare quorum, but it is not representative business. Especially is this the case under our method of selecting officers. Officers nominated by only a few members may not, and very probably do not,

meet with the approval of a majority of the members, and it may frequently happen that the ticket that would best advance the society's interest is not chosen because the members will not take the trouble to attend the meetings and do the duty they owe as members.

Another thing, it seems to me, is that the society should have some special object or objects to accomplish. There are many things that could be done by an organization such as ours. We could become a power for the betterment of conditions where found unwholesome. Some special condition to be corrected should be taken in hand, and the influence of the society urged against it until it was righted. When that is done, take up another, and another, and in this way have something at all times for which all the members could work. What a power to accomplish things can be wielded by 100 determined men, and what an influence for good we can assert if we direct our power as a unit to its accomplishment. Without something of this kind, the members are not held together in any common cause and we become simply individuals belonging to a society, each perhaps pulling opposite to the other. We are in a position now to *do* things, which, as a smaller society, we might not have attempted, and I feel sure that from now on, the society will make itself felt in the great future progress of this commonwealth. I might mention other matters in this connection, but I will not trespass further on your time.

In conclusion, I wish to thank my brother officers and directors for the assistance accorded me throughout the year, without which I could have accomplished very little. To the Membership Committee is due the credit for the marked increase in our membership during the year, and to our worthy secretary is due much credit for hard work performed under adverse circumstances.

[NOTE.— Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by April 15, 1908, for publication in a subsequent number of the JOURNAL.]

SOME OF THE ENGINEERING PROBLEMS INVOLVED IN THE CONSTRUCTION OF A DEEP WATERWAY FROM THE GREAT LAKES TO THE GULF OF MEXICO.

By J. A. Ockerson, Member of the Engineers' Club of St. Louis.

[Read before the Club, February 5, 1908.]

The remarkable revival of interest in the development of waterways, and particularly the deep-water project from Lake Michigan to the Gulf of Mexico, by way of the Illinois and Mississippi rivers, opens up questions of vast importance not only to the people of the Mississippi Valley, but to the whole country. The discussion of the methods to be employed and the benefits to accrue ought to be of unusual interest at this time. The subject covers so large a field that only a few salient points can be touched upon in the permissible limits of a paper before this club. It is hoped that its presentation here may result in a general discussion which will serve to increase the public interest in the proposed work and contribute something of substantial value toward a satisfactory, practicable solution of the problems involved in the development of a trunk line waterway between the Great Lakes and the Gulf of Mexico.

Lake Michigan to the Mississippi River.

A project for a waterway from Lake Michigan to the Mississippi River by the way of the Illinois River dates back to the earliest settlement of the country. Quite a number of surveys, plans and estimates, looking to the accomplishment of the desired result, have been made since that time.

The state of Illinois, with the aid of land grants voted by Congress, constructed the Illinois and Michigan Canal, which was opened to traffic in 1848. It begins 6 miles from the lake in the Chicago River and terminates at the head of navigation on the Illinois River at Lasalle, a distance of about 97 miles. Below Lasalle the Illinois River has been improved by locks and dams, both the state and the United States having contributed to this work. The project for improving the river provided for a navigable channel 7 ft. deep, the locks being 75 ft. wide by 350 ft. long.

When the Chicago Drainage Canal was authorized by the

state of Illinois, the project for a 7-ft. waterway was practically abandoned and the state declared itself in favor of a waterway not less than 14 ft. in depth, to be constructed by the United States from Lockport to Lasalle, the locks to be constructed in such manner as to permit of future development to a greater capacity if required.

In 1902 Congress provided for a board of engineers to determine the feasibility of constructing a 14-ft. waterway from Lockport to Grafton on the Mississippi River, and called on the Mississippi River Commission to furnish like information for the Mississippi River from Grafton to St. Louis. Plans and estimate of costs were required by the act.

In 1905 the reports were completed. The plan of the Board of Engineers proposes to canalize the river from Lockport to Utica, a distance of 63.5 miles, the fall being 136 ft. Nine locks and 5 movable dams are proposed, the upper lock having a lift of about 40 ft. The lock dimensions prescribed are 80 ft. wide and 600 ft. long, with a depth of 14 ft. over the miter sill. Concrete construction is provided for the lock walls, and the gates are to be of steel, the upper end of the channel to connect with the Chicago drainage canal at Lockport by means of a lock constructed by the Sanitary District.

The Sanitary District has already constructed a navigable canal with a depth of 22 ft. It has a length of 36 miles and constitutes a navigable channel which can accommodate the largest vessels on the Great Lakes.

The Board of Engineers were only required to consider the question of navigation; hence the development of water power in connection therewith was not discussed. If the utilization of the water power that could be developed in connection with the improvement becomes a part of the project, then a different arrangement of the locks proposed will be desirable.

From Utica to Grafton, a distance of 229.5 miles, the work proposed is to dredge a channel 200 ft. wide at the bottom, with a depth of not less than 14 ft. at low water. This involves the excavation of 27 867 060 cu. yd. of earth and 40 989 cu. yd. of rock. The estimated cost of the projected improvement from Lockport to Grafton is $23 543 582. The estimated cost of the reach from Lockport to Utica averages $241 822 per mile; from Utica to Grafton, $35 676 per mile.

The low-water slope from Utica to Grafton is about 0.14 ft. per mile, or a total fall of only 33 ft. in 229 miles.

The low-water discharge of the river at Utica is about 500

cu. ft. per sec., and this amount would be wholly inadequate for a channel of the dimensions named. The constant volume of 10 000 cu. ft. per sec. drawn from Lake Michigan through the drainage canal will, however, provide ample flow for purposes of navigation, and will also permit the development of a large amount of power above Utica. The total power that can be developed is estimated at about 135 000 horse-power, assuming a flow of 10 000 cu. ft. per sec. from Lake Michigan.

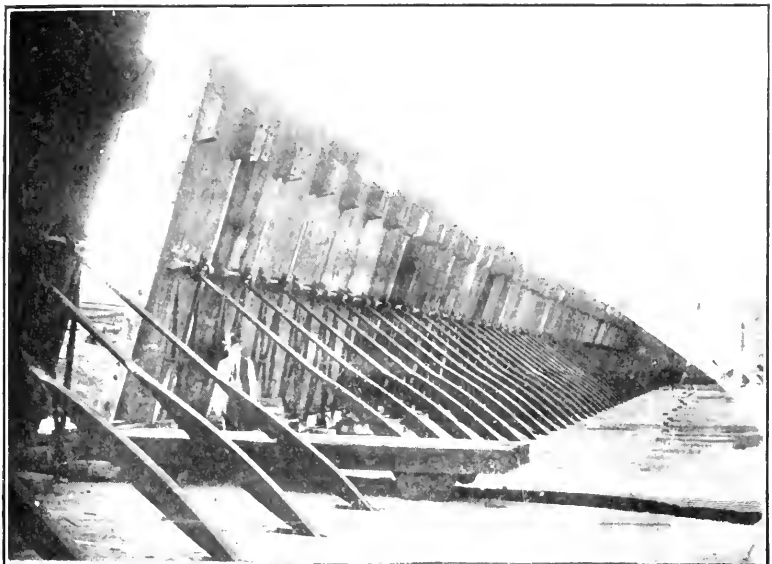
The state of Illinois proposes to undertake the whole improvement, including the water-power feature. When completed, the navigable channel will probably be turned over to the United States without charge, the chief stipulation being that the channel be perpetually maintained at the expense of the general government, the state retaining control of the water power.

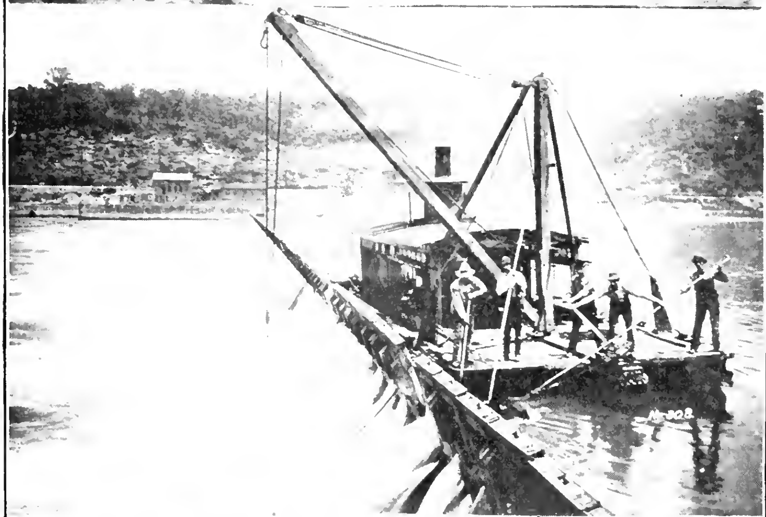
Mouth of Illinois River to St. Louis.

From Grafton to the Merchants Bridge at St. Louis, a distance of 38 miles along the Mississippi River, the problem of improvement differs materially from that of the Illinois River. The Mississippi River Commission was charged with the development of plans for the improvement of this reach. The work was done by a committee of three, the writer being a member thereof. Mr. F. B. Maltby, a member of this club, had charge of the field investigations and development of details under the direction of the committee.

The Missouri River is a disturbing element in the regimen of this reach of the Mississippi. The high-water or low-water conditions in the two streams are rarely co-incident, and hence there are frequent changes in slope, acceleration or decrease in velocity, and consequently rapid and frequent changes in channel depths. The development of deep water in an open channel under such conditions presented so many difficulties, with considerable doubt as to the ultimate success of any plan along such lines, that it was finally deemed best to avoid the difficulty altogether.

The plan adopted provides for a dam of the Chanoine Wicket type, located just below the Alton bridge; a lift of 14.5 ft. forms a pool which raises the low-water surface at Grafton about 8 ft. and in which ample depth can be maintained by a moderate amount of dredging. The dam would be about 2 500 ft. long, the sill or base being a solid bed of concrete supported on piling, the top of the sill to be 3.5 ft. below the low-water mark, or not far from the surface of the natural bed of the stream. Rows of





Movable Dam such as may be used above Cairo, showing wickets raised.
Appliances for raising or lowering wickets.
Movable Dam showing wickets down. (*Courtesy of Col. Wm. T. Rossell.*)

sheet piling are provided to prevent scour beneath the dam. At high stages this dam will be dropped down and will present but slight obstruction to the free flow of water, and at such times navigation will follow the open river.

From the east end of the dam to the Merchants Bridge a canal is planned to follow along near the river, and the water surface level of the pool above the dam will be carried down to the lower end of the canal, where a lock with a lift of 30 ft., 80 ft. wide and 600 ft. long permits of the passage of vessels from the canal level to the deep water of St. Louis harbor. That is to say, with the dam in operation during the low-water period, there will be slack water navigation 14 ft. in depth from the mouth of the Illinois River to the Merchants Bridge, a distance of about 38 miles.

At the upper end of the canal, guide piers of concrete are provided to make the entrance easy. A pair of guard gates is also planned to regulate the influx of water at flood stages.

The gates, walls and embankments are to be built to a height well above the highest known floods. The canal itself is 18 miles in length. The bottom width is 160 ft., with side slopes of 1 on 2, a berm being left 5 ft. below the water surface to support a covering of riprap some 10 ft. in height to protect the banks from wave wash.

The canal is wholly in excavation, and the earth therefrom will form an impregnable levee along its entire length, and when constructed will effectually eliminate all danger from floods in that vicinity, provided similar protection is carried from its lower end down stream. Thus a large proportion of the expense involved in the thorough protection of the American bottoms from floods is provided for in this project.

The estimated cost of the work from the mouth of the Illinois River to St. Louis is $6 553 880, or about $172 470 per mile. This is a good round sum, but unusual difficulties are involved, and little or no doubt exists as to the complete success of the project proposed. After all, the estimated cost per mile is materially less than the cost of bank revetment alone on the lower river. Taken as a whole, the project of a 14-ft. waterway from Lockport to St. Louis can be successfully carried out as planned, or if commerce demands it, even greater depths can readily be secured.

St. Louis to Cairo.

From St. Louis southward the deep-water problem is in the hands of a board of engineers who are actively engaged in the

investigations necessary to a clear understanding of all questions relating to the means of developing a suitable channel 14 ft. in depth. I doubt not that when their labors are completed and their report is submitted it will be found that they have worked out quite as good a solution as is presented in the projects for the improvement from Lockport to St. Louis.

The reach from St. Louis to Cairo, a distance of 180 miles, presents greater difficulties in the development of a deep waterway than any portion of the route from the Lakes to the Gulf, and the best course to pursue has not yet been fully determined. One serious feature is the excessive slope, which averages about 0.6 ft. per mile at low water, and another is the influx of sediment from the Missouri River.

It is, of course, desirable to have an open channel, free from all obstructing locks if practicable, as under such conditions the capacity of the waterway is practically unlimited. It might be that this could be attained by holding the water back by submerged dams or other regulation works, supplemented by dredging.

The total slope at low water is about 109 ft., and any method of deepening the channel involves the diminution or elimination of the slope in reaches of suitable length dependent upon local conditions. Locks and dams at suitable intervals would accomplish this result, but there is no precedent for their use in a stream so heavily charged with sediment, which might have a tendency to fill up the pools in a very short time. Whether a combination of flushing and dredging can be devised to meet this difficulty is a question worthy of serious consideration, and it is quite probable that a satisfactory solution can be reached.

A canal parallel to the river could be constructed without any serious difficulty. Its capacity would, of course, depend on its size, and this must be determined by a compromise between cost and the demands which would probably be put upon it by traffic. While the movement of vessels in a canal would necessarily be slower than in an open channel, it would be free from the present difficulties encountered in upstream navigation.

It seems probable that a combination of the three types of construction suggested, applied to different sections of this reach, will prove to be the most economical and efficient solution. With the volume of water available at the lowest stages, augmented as it will be by the addition of 10 000 cu. ft. per sec. or more from the Great Lakes, there is little or no room to question the feasibility of developing and maintaining, by adequate means,

a navigable channel not less than 14 ft. in depth. Whatever the project adopted may be, it will necessarily involve more or less bank protection and dredging.

The project under which improvement work has been carried on in this reach provides for the development and maintenance of an 8-ft. channel at all stages except when the river is closed by ice. The construction work embraces bank revetment, contraction of channel by means of dikes and low-water dredging. All of this work has been successfully prosecuted for a number of years, so far as the appropriations would permit. A thorough examination made during the low-water season of 1907 showed a navigable channel 8 ft. in depth.

Cairo to the Gulf of Mexico.

From Cairo southward the problem of deep-water development changes again. Here the river enters the great alluvial basin and flood control becomes an essential feature of any plan of improvement.

The low-water volume which at Utica is 500 cu. ft. per sec. omitting the lake contribution, at St. Louis 40 000, here becomes over 70 000 cu. ft. per sec. at low-water, and 1 600 000 cu. ft. per sec. at high water. The low-water slope from Cairo to Red River averages 0.35 ft. per mile, or about one half the average slope from St. Louis to Cairo.

Under natural conditions, without improvement, a navigable depth of 14 ft. is available for six months or more each year, even in exceptional low-water years. The obstructing bars which would require deepening to 14 ft. lie between Cairo and the mouth of the Red River, a distance of 765 miles. The 300 miles of river below the mouth of Red River has ample depth at all seasons of the year, even for ocean vessels.

The improvement below Cairo is under the control of the Mississippi River Commission. Under the present project the work consists of the construction of levees for the control of floods, the maintenance of a channel "not less than 9 ft. in depth at all stages except when closed by ice," and the revetment of banks for the purpose of preventing cut-offs through narrow necks of land, the protection of important levees and the water fronts of cities.

Flood Control.

The levees now reach a length of about 1 450 miles. The several states have had the largest share in the cost of their

construction. The character of work required is fixed by the plans and specifications prescribed by the Mississippi River Commission.

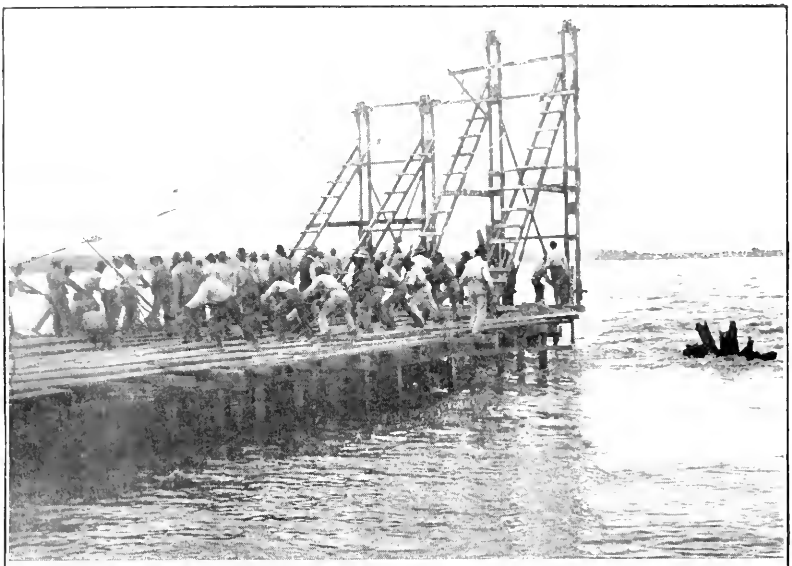
The levee system is by no means complete, either in height or section, yet it affords a good measure of protection. This is shown by the fact that the flood of 1907, which has only been exceeded six times in the past 40 years, and reached within 1.8 ft. of the highest recorded flood, was carried down for 975 miles without a single break in the levees. The development of the Alluvial Valley due to such protection has been little short of phenomenal. In a brief space of time the tangled wilderness has given place to fertile fields, and many thriving towns and villages have sprung up.

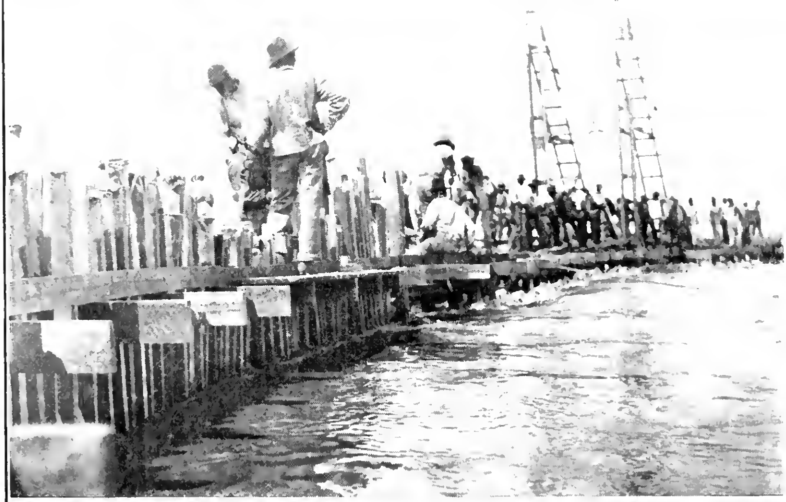
Dredging for a Nine-Foot Channel.

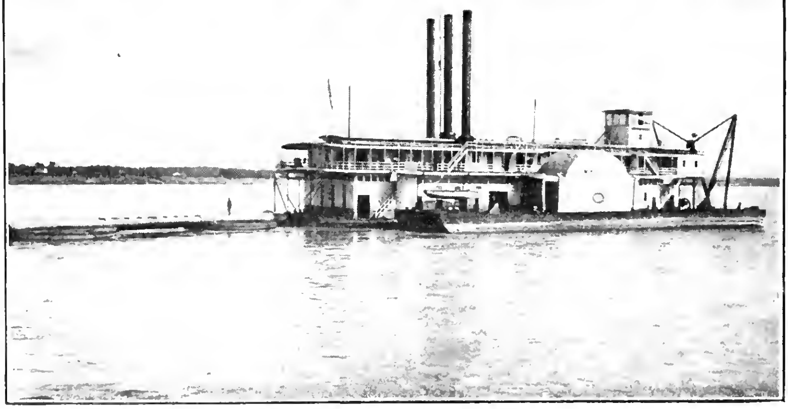
The dredging work required to maintain a 9-ft. channel is almost entirely confined to the first 250 miles below Cairo. There are only about 40 bars or crossings in the entire reach, Cairo to Red River, which may develop shoals with less than 9 ft. thereon. They have never been known to be shallow at the same time, and it very rarely occurs that even one half of them become obstructions to navigation in any single low-water season. The largest number of bars dredged in a season down to date is 17. During the last three years only 5 bars have required dredging each year, and but few of the bars show lack of depth at the same time. A crossing with deficient depth one year may have ample depth for several years in succession. As a general rule, shallow bars are looked for in a few well-defined localities each season. A very large percentage of the 765 miles shows depths of 9 ft. or more at all stages, leaving a comparatively small amount with deficient depth which must be increased by artificial means. Furthermore, the duration of the low-water period, when the depth may be deficient, does not exceed five months in the year as a maximum, and is more often covered by a period of three months.

Under the project cited, little difficulty has been experienced during the past six years in maintaining a 9-ft. channel by means of dredging. The Mississippi River Commission has 9 available dredges, but only 5 of these have been needed during the low-water seasons of the past 5 years. The work required to maintain a channel varies greatly with different seasons, but it does not depend wholly on the variations of stage. The vertical oscillations of the bed of the river itself conform in a great meas-

A Break in the Levee below New Orleans.
Levee-building Device with $2\frac{1}{2}$ yd. Scraper Bucket.
Levee built therewith.







Closing Crevasse in Levee.
Pile Work finished and Cribs being filled in.
Latest Hydraulic Dredge. Capacity, 1 600 yd. per hour. Discharge pipe, 36 in. diam. Suction head, 32 ft. wide.

ure to the changes in stage. A channel 10 ft. deep at a 10-ft. stage may still have 6 ft. or more in depth after a fall of 8 ft., or there may be even a less depth at a higher stage.

It will be seen, therefore, that the problem of maintaining a deep channel in a silt-bearing stream is somewhat complicated, in that it is impracticable to determine beforehand how much work will be required in any low-water season.

Experimental Dredging for a Deep Waterway.

The Mississippi River Commission has had three dredges at different crossings during the past low-water season, testing the practicability of developing and maintaining depths of 14 ft. or more by means of dredging. So far as the experiments have gone, the indications are decidedly favorable. Channels of such depth have been developed and maintained without difficulty.

The dredging for channels 14 ft. in depth was done at Linda, 82 miles below Cairo; Island 35, 192 miles below Cairo; and Corona, 204 miles below Cairo, and the following results were obtained:

Linda was dredged three times following changes in stage, and a 16-ft. channel was developed and maintained.

Island 35 crossing was dredged four times, giving a channel depth of 17 ft.

At Corona the dredge cuts were from 7 to 12 ft. in depth and channel depths of 16 ft. were secured.

It is proper to say, however, that the low-water conditions during the season were not such as to require a great amount of dredging, as the river was somewhat above the normal summer stage.

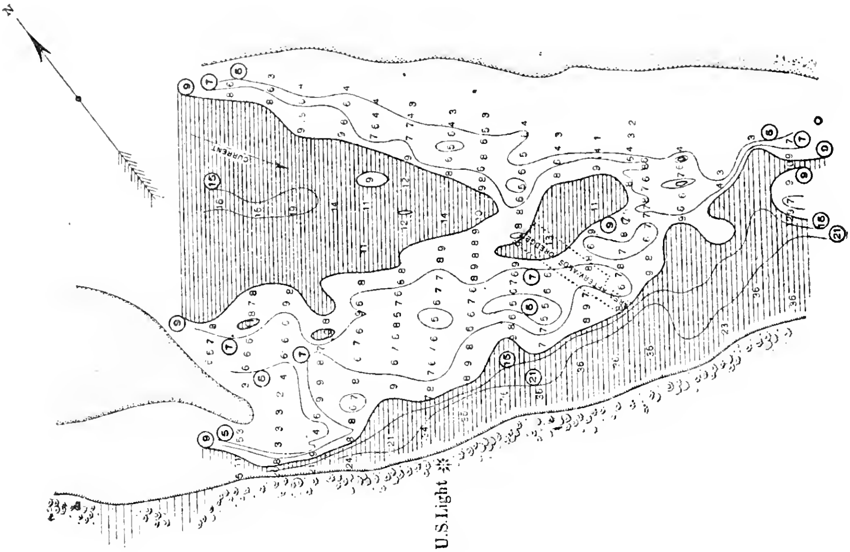
Normal Channel Conditions.

There is not a foot of the entire length of the river from Cairo to the Gulf of Mexico which has not depths of 14 ft. or more at all stages in some portion of the cross-section. That is to say, the pools overlap one another and are separated by the obstructing bars or crossing.

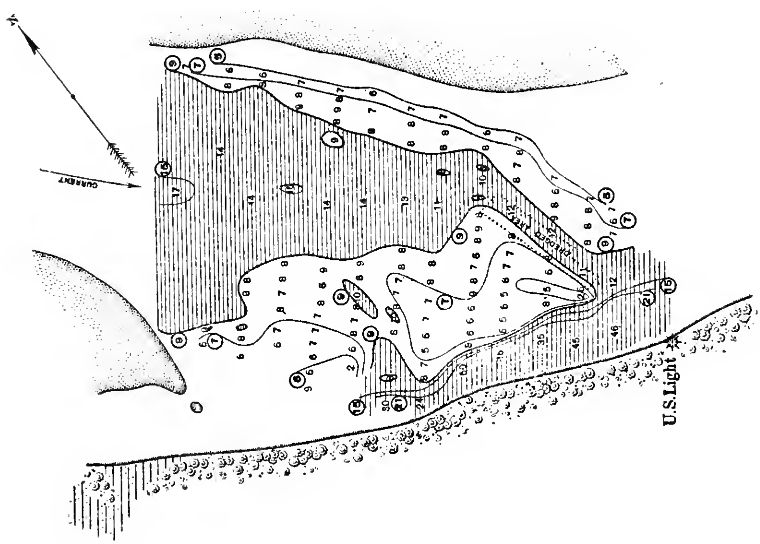
Just what depth may be found on any crossing at low water can only be determined by actual soundings at low-water stage. It must be apparent, owing to the shifting character of the river bed, that soundings taken at higher stages and reduced to low water would be greatly misleading and of no value in deducing low-water depths.

Surveys were made during the low-water season from Cairo

to Corona, 203 miles, in 1902; from Corona to Arkansas River, 198 miles, in 1904; from Arkansas River to Vicksburg, 198 miles, in 1894; and from Vicksburg to Red River, 165 miles, in 1895.



Bar or Crossing before Dredging.



The Same Bar or Crossing after Dredging.

A careful examination of the results of these surveys, covering 765 miles of the river, shows that there were 9 crossings in the first-named reach, with depths less than 14 ft.; 5 crossings in the second reach; 10 crossings in the third reach; and 4 crossings

in the fourth reach; or a total of 28 crossings, with an aggregate length of 43 200 ft., or a little over 8 miles and about one per cent. of the total distance. Had the surveys of the two first-named reaches been made during the extreme low-water seasons of 1894 and 1895 when the other two reaches were surveyed, there is little doubt that a greater number of deficient crossings would have been found.

An investigation made in connection with dredging during the lowest water of the season of 1904 showed 33 crossings with depths less than 14 ft. between Cairo and mouth of Arkansas River. This number would be excessive, if anything, as no special effort was made to follow the line of deepest water.

The lowest stages so far recorded occurred during the years 1894 and 1895 and the low-stage conditions were prolonged. The 14 crossings, showing less than 14 ft. in depth between the mouth of the Arkansas River and Red River, may, therefore, be regarded as representing extreme low-stage conditions. It may be said further that only four crossings between Vicksburg and the Gulf of Mexico, a distance of 470 miles, showed depths less than 20 ft.

In view of the foregoing facts, it does not seem probable that the total number of crossings or bars below Cairo with channel depths less than 14 ft. will ever exceed 45 in number in any one year. Assuming an average length of a mile each, which is undoubtedly excessive, the aggregate length would be about 4.2 per cent. of the total distance. So the elimination of these bars by means of regulation works and dredging cannot be regarded as an exceptionally formidable task.

There has been a good deal of speculation as to the effect of dredging through a bar in lowering the pool above. If this actually occurred to an appreciable extent in a succession of bars and pools, it might become serious. The most careful measurements, however, fail to disclose any such results.

Little or no enlargement of the cross-section of the stream occurs, as the overlapping portions of the pool sections are largely eliminated by connecting them with a dredged channel.

Bank Erosion and Its Prevention.

By far the greatest source of supply which contributes to the development of sand bars in the lower Mississippi River is the erosion or caving of the banks. The volume of solid material per annum from this source amounts to an average of 9½ acres 66 ft. deep for each mile of river between Cairo and Donaldson-

ville, a distance of 885 miles, or over a million cu. yd. for each mile of river, a quantity quite sufficient to account for all of the sand bars; and it is hardly fair to charge the Missouri River with furnishing all or even a very large percentage of the material that contributes to the obstructions to navigation between the mouth of the Ohio and the Gulf.

In the reach below Cairo the development of a deep channel will necessarily include the fixing of the badly caving banks, and this will doubtless prove to be the largest item of expense. The work of the Mississippi River Commission, extending through a number of years of experimental work, has developed a type of revetment which is found to be equal to the task of holding caving banks even in the most difficult bends of the river.

The problem presented is by no means an easy one. The banks often extend 40 ft. or more above low water, while the thalweg of the river bed lies 60 ft. below the same. Thus we have a saturated bank about 100 ft. high resting on a base of silt which is readily moved by the rapid current. Comparatively slight obstructions to the current cause whirls and eddies which are destructive in their effect, sometimes undermining the revetment, unless it is carried well out into the stream.

Experience developed the necessity of wide mattresses, 300 ft. in width in some cases, instead of 100 ft. as used in the earlier work. It also proved that spur dikes at intervals of 450 ft. cannot be relied upon to hold the banks without continuous revetment between. To be effective the interval must be so small that their use is no longer regarded as advantageous or economical.

The standard revetment as now used consists of a mattress of willows heavily weighted with stone, covering the bank from near the low-water line down. The upper bank is graded to a slope of 1 on 3 by means of hydraulic grades, and is then paved with stones laid upon a layer of spalls.

This type of revetment can be relied upon to hold the banks in the most difficult situations. It is manifestly not permanent in the sense that it will need no care after it is put in. Like most engineering or other structures, revetment must have constant care, but if properly placed in the first instance the cost of maintenance will not be excessive.

In New Orleans harbor the length of revetment is over five miles, some of which has been in place more than 20 years, yet there has been nothing expended in repairs and maintenance direct, other than that chargeable to plant and administration.

This revetment consists of spur dikes at intervals of about 450 ft., with standard revetment between.

The total length of revetment in place below Cairo to date is 39.6 miles. The repairs and maintenance, including all charges, varies in different localities, from less than one to about five per cent. of first cost. The latter figure may be regarded as quite excessive and will no doubt be largely reduced by the present methods of construction. Efforts are now being made looking to the development of longer field seasons whereby the plant can be used for a longer period each year, the result of which would be a material reduction of cost. Heretofore the field operations have been confined to the low-water season of three to five months.

The experience gained in this work is a most valuable asset, but it has been at the expense of much time as well as money, and the element of time is the more important of the two. Before a work can be looked upon with any degree of confidence it must pass through all the cycles incident to changes of stage, which necessarily requires many years, and this test cannot be hastened by any known means. But with the experience acquired by many trials, supplemented by careful, systematic observations, we can now proceed with confidence in our work, feeling sure that it will meet the requirements in a satisfactory way.

Character of Works Required.

There will be no great difference of opinion among those who are familiar with the conditions as to the general plan to be followed in the development of a deep waterway below Cairo. The essential features must be, a combination of flood control by means of levees, bank protection, dredging and a limited amount of contraction work where the channel width is excessive. The proper use of such works will develop a deep-water channel at all stages of river throughout the lower two thirds of the proposed "Lakes to the Gulf" waterway. In this reach the physical conditions are thoroughly understood, the means to be used have long since passed beyond the experimental stage and a fair estimate of the cost of a channel of such depth as may be required can be made from the data now in the possession of the Mississippi River Commission.

It would, therefore, seem to be good policy to begin systematic work on this reach at once, looking to the development of such depth of water as may be deemed necessary to meet the future demands of commerce. The organization is ready, a

large portion of the plant needed is on the ground and it is only necessary to decide as to the limiting depth, when the work could proceed systematically on the lower thousand miles of the waterway pending the results of the elaborate investigations required for the 180 miles between St. Louis and Cairo.

Since the unanimous declaration of the Illinois legislature in favor of a bond issue for the construction of a deep waterway to the Mississippi River at Grafton, 329 miles from Lake Michigan, and the fact that good results are practically assured for the lower 1 070 miles below Cairo, it does not seem at all probable that such formidable obstacles to the proposed improvement between St. Louis and Cairo, 180 miles, will be met with as to seriously menace the practicability of the entire project.

The work required from Grafton to St. Louis with estimated cost has also been definitely determined. So, out of a total distance of 1 625 miles from Lake Michigan to the Gulf of Mexico, there are only 180 miles concerning which there is much doubt as to the best methods of securing the depth desired, and even in this limited reach there can be no reasonable doubt as to the possibility of securing such depth as may be required.

The opening of the Panama Canal should see the work on the deep waterway well on toward completion, and it would seem to be wise to begin work at once, since the proper line of procedure for more than two thirds of the entire work is already quite clearly defined.

Ample Terminal Facilities Essential.

The easy and expeditious transfer of freight at the great shipping centers is quite important. The lack of facilities therefor has been attributed to the difficulty of installing suitable terminals on account of the oscillations of stage in the river. The extreme range of stage recorded at St. Louis is 44 ft.; Cairo, 53 ft.; Memphis, 43 ft.; Vicksburg, 59 ft.; Natchez, 51 ft.; New Orleans, 21 ft.

While these conditions complicate the problem somewhat, there are no great difficulties in the way of designing and constructing fireproof warehouses along the river fronts which would greatly simplify the loading and unloading of boats and barges and provide for the interchange of traffic with the railways direct without the usual drayage.

Some years ago the writer suggested the construction of a series of warehouses along the river front at St. Louis, beginning at the Eads Bridge and extending downstream as far as neces-

sary to accommodate the traffic, the warehouses to have several floors for the convenience of the water traffic, the surface and elevated roads, and goods that came by wagon, all to be provided with suitable elevators, which could shift loaded trucks from one floor to another, where they could be rolled away to the desired point of delivery. Suitable conveyors, inclined and horizontal, would also expedite the handling of freight. These warehouses were to be reached from the business portion of the city by elevated driveways, which would eliminate a large part of the steep hill between Third Street and the levee. The great value of such terminals to both water and rail traffic must be apparent.

The city of New Orleans has actively begun the construction of extensive warehouses and freight platforms along the river front, with a belt line of railway along the land side thereof, for the easy and rapid interchange of freight. Her example should be followed by other important shipping centers in order that the fullest benefits to be derived from water transportation may be realized.

At St. Louis and other points, wharf boats rising and falling with the stage of river have been in common use, but the drayage over the steep levee has always been a serious drawback. This method does not permit of a direct interchange of freight with railways, as the wharf boat moves laterally along the slope of the levee as well as vertically, as the stage of the river changes.

Warehouses, called elevators, for handling package freight, were formerly used with success at Memphis, Vicksburg and Natchez; and at New Orleans conveyors are now used to carry the freight to the top of the wharf or levee.

For facilitating loading or unloading at way landings, river craft should be provided with conveyors attached to the stage plank so that freight could be landed at the top of the bank without using the great amount of time and labor incident to present practice.

Where the cargo is destined to foreign ports, the transfer can be made direct from river to seagoing craft, and in this way storage and warehouse charges would be materially reduced.

Improvements of the kind named are next in importance to better channel conditions and in a general revival of river traffic should receive the fullest consideration.

Value of Waterway as a Transportation Highway.

As the deep-water project proposed will involve the expenditure of large sums of money, it is proper to inquire as to what

benefits may be expected to accrue by its construction and use. Before any project is adopted, it should be pretty clearly established that the sum of all the benefits will be fully commensurate with the cost. When this has been satisfactorily settled, the cost of the project, though great, becomes a matter of secondary importance.

In a project of such great magnitude, these questions of cost and value, especially the latter, cannot be determined with any great degree of exactness. The same thing is true to a certain extent of all great engineering works, —the Suez Canal, the Manchester Ship Canal, the great transcontinental railways, the New York subways. In all of these cases the benefits that justified the works could only be roughly estimated when the projects were undertaken, and in nearly all of them the estimates of the benefits were altogether too conservative. And it is not improbable that the value of a trunk line waterway of great capacity, such as proposed, will also be underestimated even by its most enthusiastic advocates.

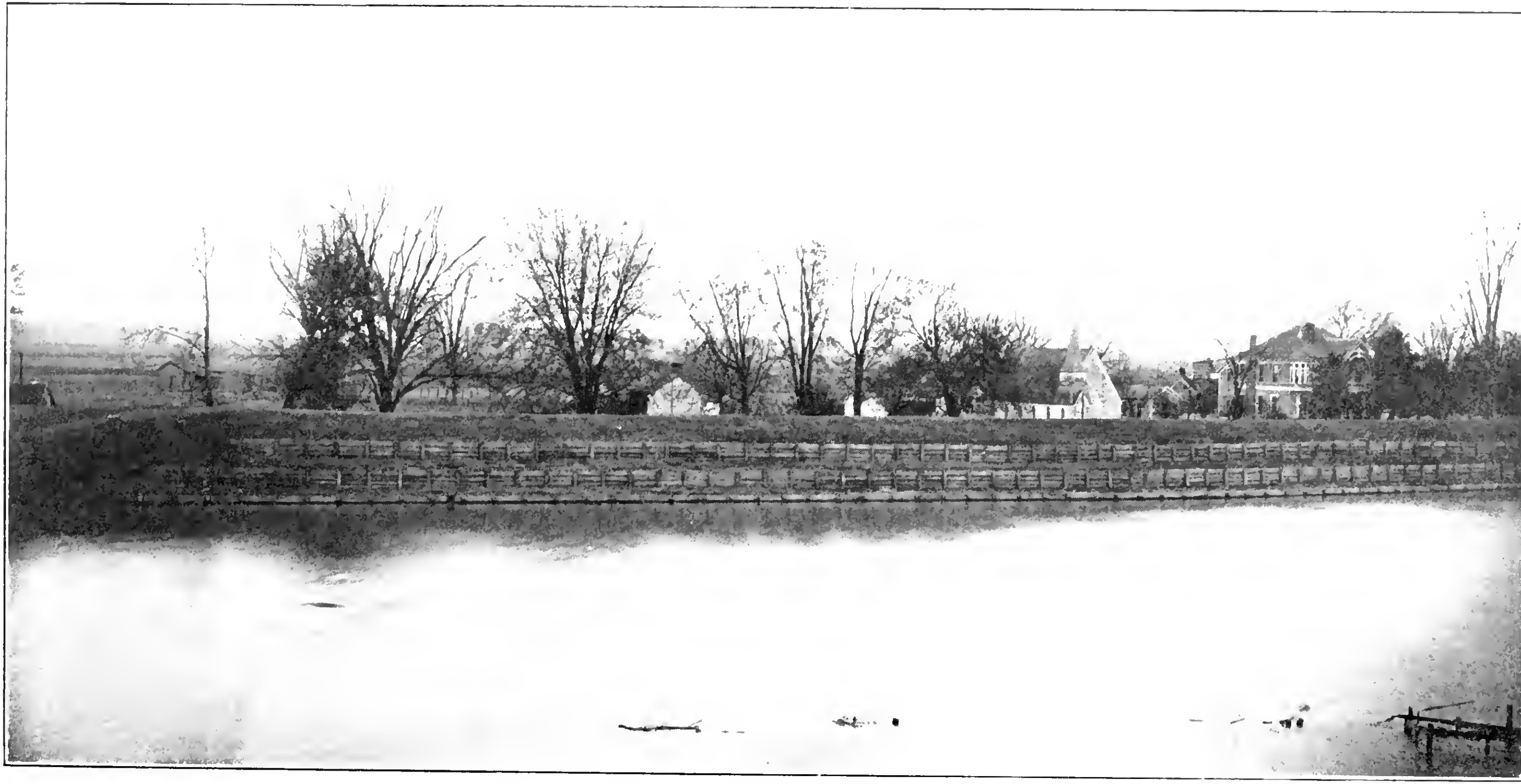
The writer devoted considerable time to gathering statistics of the freight movement by river and by rail from the port of St. Louis for the years 1865 to 1900. These data were published in the report of the Mississippi River Commission for the year 1901 and have been widely quoted since that time.

The grain traffic by river did not assume important proportions until 1877, owing to the general belief that grain exported by the way of the warm, humid Gulf route would be damaged in transit, although the St. Louis Grain Association virtually settled the matter in 1869 by sending 500 000 bushels of wheat to Liverpool, which reached its destination in good order. The lack of depth at the mouth of the river prior to the construction of the jetties was also a serious drawback.

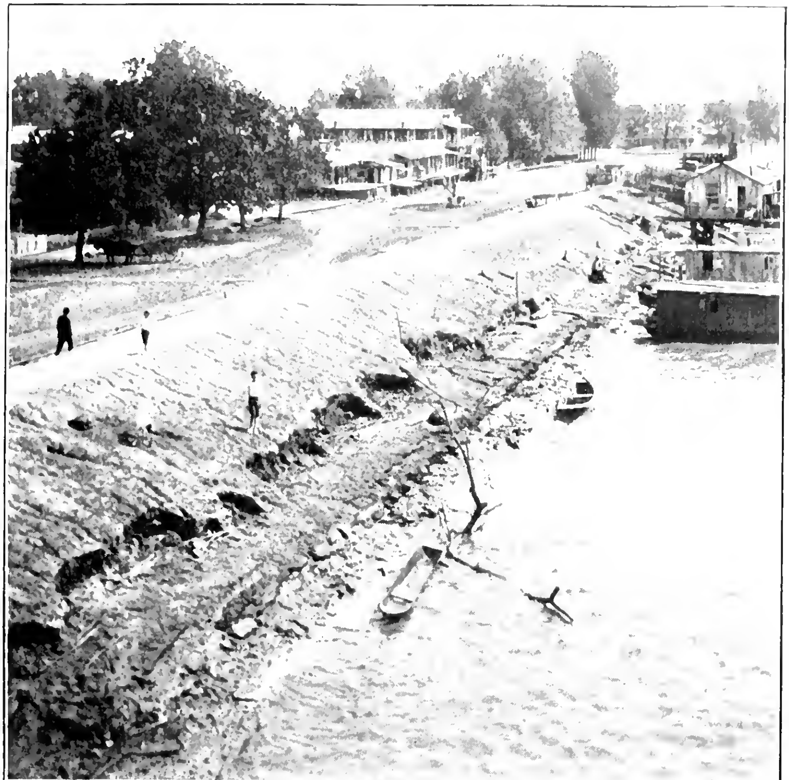
The maximum rate on wheat by rail from St. Louis to New York reached 72 cents per bushel in 1867. In 1877 the rate was 24.6, and in 1900 11.6 cents per bushel, as against $8\frac{1}{4}$ cents in 1877 and $4\frac{1}{4}$ cents in 1900 from St. Louis to the seaboard at New Orleans.

From the exports for 18 years, 1883 to 1900 inclusive, for which complete data are available, some interesting deductions may be made. The total number of bushels of grain exported from St. Louis during this period was 761 004 715 bushels. The average rate per bushel, St. Louis to Liverpool by river and Gulf route, was 6.85 cents less per bushel than that by rail via Atlantic ports. Applying this to the total amount exported, and we have

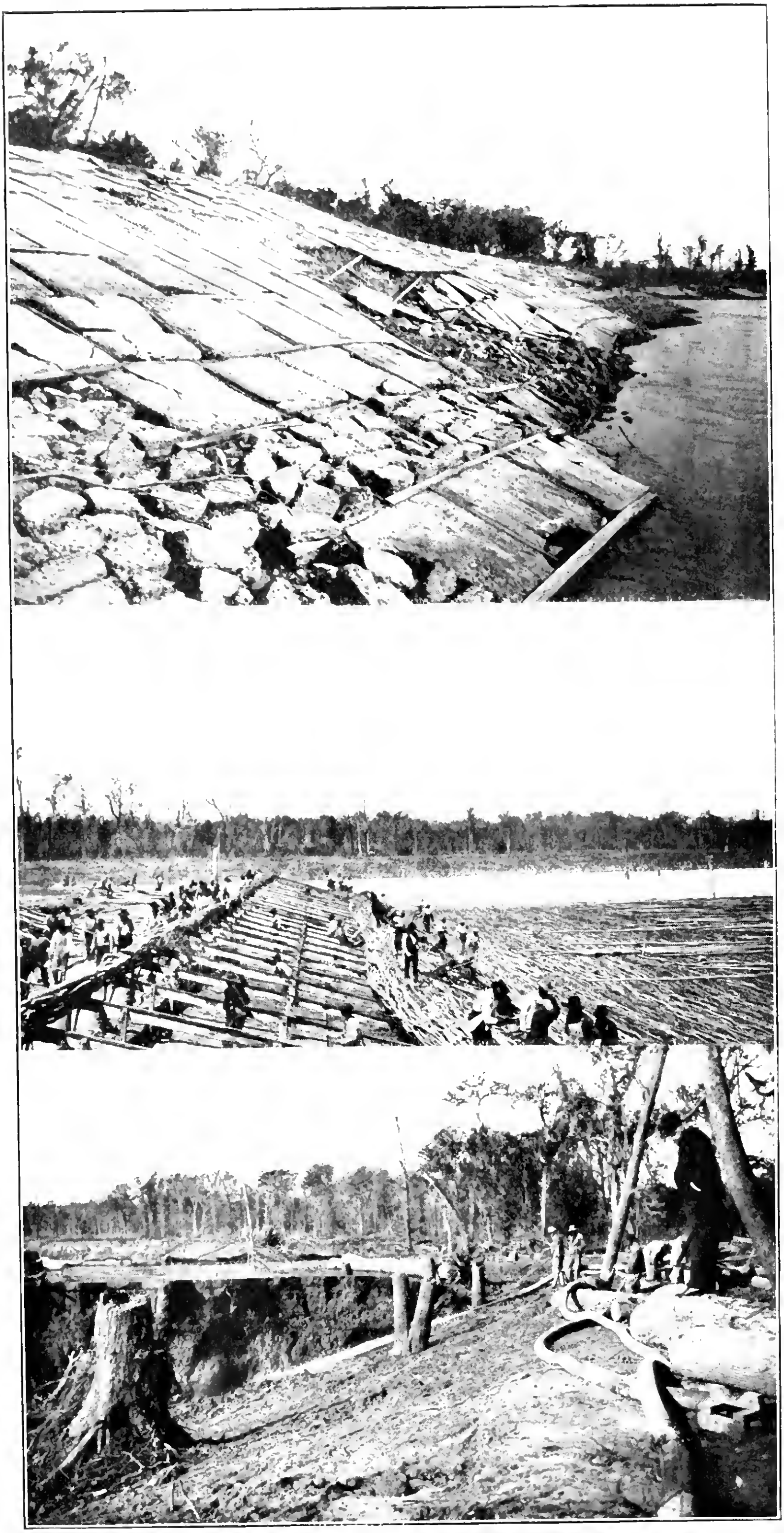
Caving Bank and Revetment Plant. Weaving Mattress for Bank Protection.



Revetment to Protect Levee from Wave Wash.



Wave Wash at Base of Levee.
Paving the Upper Bank.



Upper Bank Paving in Bank Protection.
Mat Weaving for Bank Protection.
Grading Down the Bank Preparatory to Paving.

the magnificent sum of $52 128 882.98, which might have been saved to the producer and shipper had the grain been carried by the river route. The river did actually carry 134 736 563 bushels of export grain during this period, showing an actual net saving over the rail rates of $9 229 454; this from a single port on the river and for a single commodity.

Add to this the shipments that were made of coal, lumber, cotton, sugar and general merchandise to and from this and many other ports throughout the length of the river, and we get some conception of the enormous value of the Mississippi River as a commercial highway under such improved conditions as would insure ample depth at all times.

Two illustrations will perhaps serve to emphasize the possibilities of river traffic. The steamer *Sprague*, a stern-wheel towboat of the Mississippi River type, has recently taken down at one time a cargo of 67 000 tons of coal. A recent report of the Frisco Railroad gives the average car load for the past year at 16.9 tons, and train load, 224.4 tons. On this basis it would require 3 965 cars or 298 trains to haul the single cargo named.

A notable cargo on a single hull was that of the *Henry Frank*, which carried 9 226 bales of cotton and a quantity of cotton seed at a single load. The hull of this boat was 267 ft. in length, with a beam of 52 ft. This single cargo would make about 300 carloads.

Both of these cargoes were carried at high stages of river, but they afford good illustrations of what might be done with an improved waterway with sufficient depth at all seasons.

There is a wrong impression in the popular mind as to the relative speed of transportation by water and rail. The *Sprague*, with her immense cargo in barges, would make 75 to 100 miles per day, or about four times the average speed of freight movement by rail, as given by a high railway authority.

A cargo on a single hull would easily average 150 miles or more per day.

The usual time for a tow of grain barges carrying about 12 000 tons, or say 54 average train loads, from St. Louis to New Orleans, is 8½ days, or an average of 140 miles per day, over five times the average rate of freight movement by rail.

Whatever may be the type of boat that will ultimately ply between the principal ports and the seaboard through a deep waterway, the way landings must continue to be served in a large measure by boats and barges similar to those now in use.

An improved waterway which would develop to the highest

degree the possibilities of water transportation would largely solve the question of freight congestion under normal business conditions, which has become a matter of such serious concern to railway managers. As an illustration of this congestion, it is related that an English firm of spinners bought last year at Memphis some 5 000 bales of cotton to be shipped to Liverpool via Atlantic ports. Such was the dearth of cars that the cotton remained in storage three months before it could be started on its way.

The waterway must supplement the railway by relieving it of a large volume of the low-class freight, such as farm products, coal, lumber, minerals and building material, leaving the manufactured products and higher class freights to the railways.

Raw material can be moved cheaper by water than by rail, and much that would otherwise remain inert would be brought into use to be developed into manufactured products, the distribution of which would result in increased revenues to the railways. So it is by no means unreasonable to assume that an efficient waterway will be of substantial benefit even to the railways.

Special Advantages of the Route from Lake Michigan to the Gulf of Mexico.

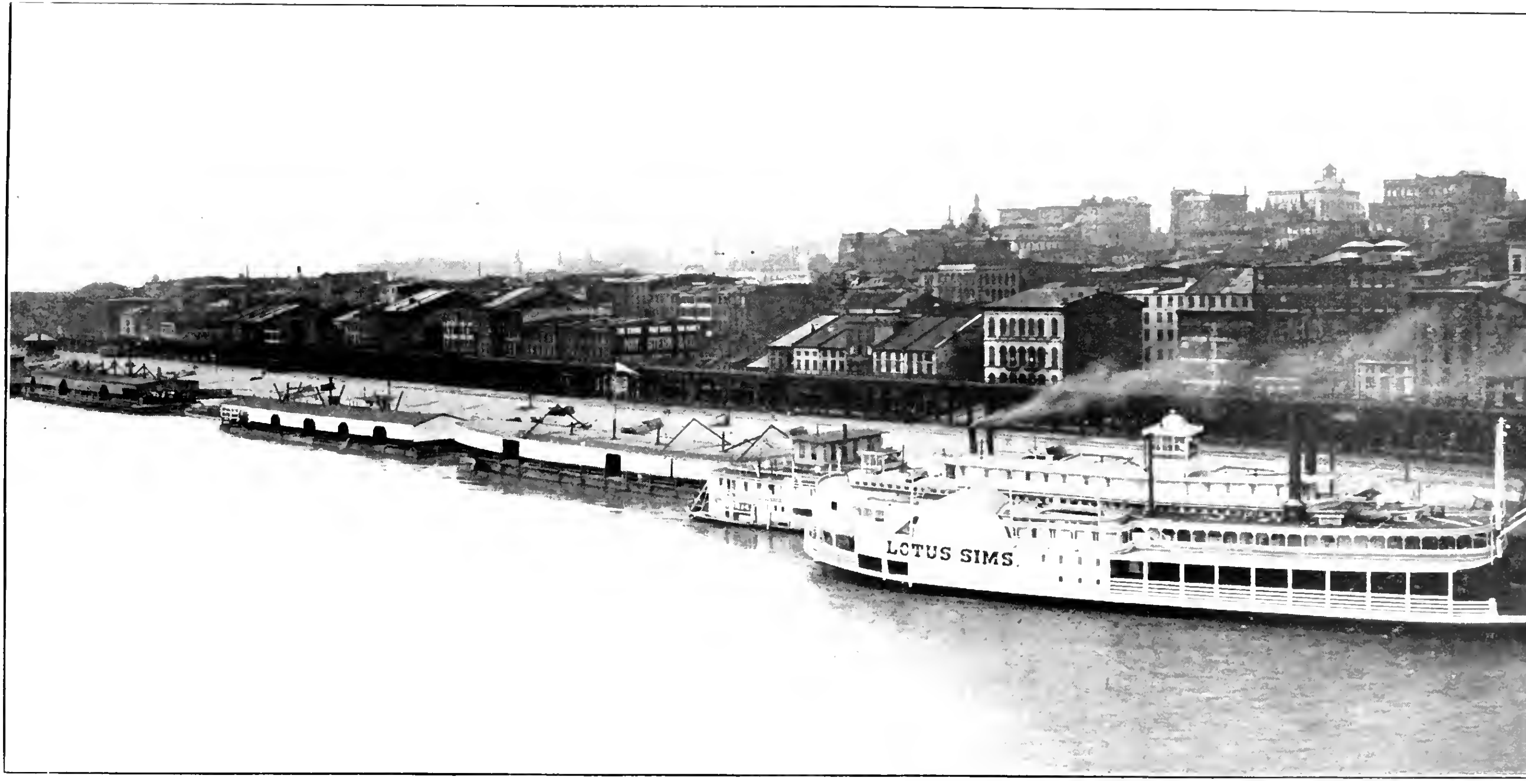
First. Its whole length lies in the very heart of the most productive section of the entire country.

Second. The great capacity of three fourths of its length as a transportation highway is without a parallel. As compared to the greatest artificial highway, it has practically unlimited capacity.

Third. Its situation as to closure by ice gives it a very decided advantage over any of the northern routes proposed. One thousand miles of its length is open to navigation practically the entire year. Even between St. Louis and Cairo the river was open 20 out of 43 years, and the closure on account of ice in the most severe winters has never exceeded 59 days. The northern routes are generally closed more than twice that length of time each year.

Fourth. The volume of water available under natural conditions, which is essential to the development of any satisfactory waterway, is far greater than that of any other route, and its capacity for improvement is proportionately greater.

Fifth. The proximity of the Gulf end of the route to the Panama Canal and the consequent advantage in trade with the



Part of Harbor and Wharf at St. Louis.

Pacific coast and the Orient, as well as the accessibility of the South American countries, gives this route a great advantage over any other in this particular field of trade and commerce.

Sixth. Its construction, in proportion to its available length and capacity, will probably cost less than any other route.

Seventh. Nature has marked a route of unequaled utility and value along the thalweg of the Mississippi Valley which the skill of the engineer can readily bring under subjection for the profitable uses of man.

[NOTE.—Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by April 15, 1908, for publication in a subsequent number of the JOURNAL.]

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WIRELESS TELEGRAPH AND TELEPHONE.

By THOMAS E. CLARK.

[Read before the Detroit Engineering Society, December 20, 1907.]

PROGRESS seems ever to be the watchword of the human race. Man is never satisfied unless he is improving on the things already done. Long before the dawn of the Christian era wireless methods of transmitting intelligence to a distance were employed. Such telegraphing, of course, was not electric, but did, nevertheless, communicate through space. The ancient Greeks had adopted a systematic method of signaling with torchlight placed on high walls, certain combinations of these signals representing certain letters of the Greek alphabet. Many remarkable instances of the mysterious powers said to be possessed by the Eastern nations of sending messages through space hundreds of miles without visible appliances have been brought to my attention in reading the history of wireless communication.

There is no doubt that many here present at one time or another have been made familiar with remarkable phenomena that could be explained in no other way than by one mind acting on another mind. To say that all are the result of coincidences would be absurd. If we do not understand certain at present inexplicable phenomena, let us at least be logical and maintain open minds, and not discredit the efforts of those who know more than ourselves.

We are surrounded with mysteries, while our vision and all our other powers are limited. There are forces and forms of

energy, undreamt, awaiting investigation, and many of them doubtless would be beneficial to the human race if we could only lay hold of them. The discovery of the X-rays is an indication of this. We have had X-rays present for many years in all experiments where high-frequency currents of electricity have been applied to Crookes tubes, yet we never realized the fact that such an aid to medical science was so close at hand. The whole nature, power and virtues of the beam of light are not yet known and so it is with many of our surroundings.

Right here I want to touch on the question, Is there anything solid? There are three or four different methods adopted by scientific men for signaling through space without metallic conductors or connecting wires, and it is evident that if we are to understand any of them we must considerably modify our ideas of the compactness of solid bodies. It becomes a question whether there is any substance so absolutely compact that there are no spaces between the atoms into which the thin medium may enter. Our idea of the opacity of wood, ebonite, aluminum, etc., underwent a complete change on the discovery of the X-rays; so it is with regard to everything that unscientific people have been accustomed to look upon as absolutely solid or compact. It is not easy to give up old ideas.

When we place a wireless transmitter or sending instrument in one room and a receiver in another room, and the electrical energy immediately passes through walls, partitions, etc., our ideas of the matter of solid bodies and compactness all receive a sudden shock and the layman wonders what we are coming to.

A few simple illustrations will help us to see that bodies which we look upon as perfectly compact must have spaces or interstices between their atoms, however close we may imagine those atoms to be together.

Suppose, for instance, that we cut down a large tree of the forest, cut off its branches and take a length of 200 ft. of immense circumference and weight of many tons; still it is not truly compact, for its atoms are separated by space. If we take a pin and gently scratch one end across the grain, so gently that we cannot hear the sounds of the scratching at our end, a friend at the other end will distinctly hear the sounds produced and will be able to tell us the exact number of times we used the pin. To do so he need not put his ear against the tree, for he can hear distinctly several inches or a foot away from the end of it. The gentle scratching with the pin has set every atom and molecule in the tree in a state of rapid vibration. The pressure of the

pin may not have been more than half an ounce, yet it is sufficient to cause such an alteration in the huge mass that waves of sound are rapidly conveyed all through it.

If there is nothing absolutely solid in nature, it follows that it is possible for a medium possessing certain qualities to permeate all things. We have the strongest reasons for believing that such a medium exists. Now we have to see how the ether is of service in the discoveries and work we have under consideration.

If a stone is thrown into the middle of a pond, a series of ripples, or small waves, covers the surface of the water. Similar waves are produced in the air whenever a bell is struck; and the ether has its waves also.

Faraday, Helmholtz, Clerk Maxwell and others have stated that light from the sun and electricity were the same in kind and that they only differed in degree, the difference resting in the lengths of their respective waves. Their velocity through space was the same, namely, 186 000 miles a second. Hertz actually proved in his laboratory that electro-magnetic waves were capable of reflection and that they were longer than those of light. This paved the way for surprising results, as we will notice later. Energy sent out from the sun receives different names. For example, we have light waves, heat waves, electric waves and so on.

It is a common mistake to credit the vibrations in air with doing the work done by the vibrations in the ether. We must draw a very wide line between the two kinds of vibrations in all experiments and work associated with wireless telegraphy. One set of vibrations, those in air, has to do with, it may be, thousands of waves per second, but those in the ether are reckoned by hundreds of millions, hundreds and even thousands of billions per second. We may easily see the difference in the behavior of the two media, air and the ether.

Suppose in a thunderstorm three miles away we see a flash of lightning; the light-waves in the ether reach the eye practically at the same instant that the flash actually occurred, because, if light be capable of traveling round this earth about eight times in one second, it would not take the sixty-thousandth part of a second to travel three miles. But what about the noise occasioned in the air by the electrical discharge? Noise or sound has to do with the other medium, namely, air, and its reception is accomplished by the ear, not the eye. The waves in the air do not travel at the same pace. The average speed

may be about 1 150 ft. a second, according to the temperature of the air. This would mean about fourteen seconds for the thunder to make itself known to us. The electric current in fourteen seconds would have gone round the earth more than a hundred times.

Another illustration may not be amiss here: A skeleton clock, with hammer and bell visible, and wound up to keep ringing for a considerable time, is placed under the glass receiver of an air-pump. As the air is pumped out the sound gradually gets weaker; we see the hammer striking the bell, but the sound is almost *nil* as the exhaustion approaches a vacuum. You cannot have sound if there be an absence of air, for there is nothing to set into vibration by the vibrations of the bell, which has been set into vibration by the action of the hammer. But there is a medium present which cannot convey sound-waves, that is, the ether. It is there, otherwise I should not be able to see the clock. This is made visible to me by the light which reaches the eye. The light waves do not require the medium air, but ether.

In accompanying scales of vibrations we see the great line of difference between waves in air and those in the ether. First we note the ordinary range of human vocal powers, including those of professional singers, and observe the wonderful range of the powers of human hearing.

Vibrations in Air and in the Ether.

THE ETHER VIBRATIONS PER SECOND.

Probably trillions		The "X-Rays."
2 000 000 000 000		Actinic rays.
750 000 000 000 to about 400 000 000 000	violet indigo blue green yellow orange red	The range of human sight.
100 000 000 000		Infra red.
230 000 000 (approximately)		Hertz waves.

AIR (SOUND) VIBRATIONS PER SECOND.

Range of human hearing	40 000	Highest audible sound.
	30 000	The shrill cry of bat.
	4 000	Highest musical note used.
	2 000	High soprano note.
	512 to 256	Woman's conversational voice.
	128	Man's voice (conversational).
	32	Lowest musical note used.
	16	Lowest audible sound.

To proceed now to the other set of vibrations, those in the ether, we are struck with the limited range of the human eye. It reaches from four hundred billions (violet). But what a wonderful power, the power to see, the power to appreciate color! Next to the right use of the mind comes in order this power to see. The ether is the medium, light the agent and the eye is the receiving instrument. The adaptability of the eye to light is a marvel in itself. But even if the eye be limited in its range, what does it matter? The mind of man applies itself, and other rays, invisible to his eye, are discovered and utilized in ways that are beneficial to mankind. Thus the mind, when properly applied, is capable of discovering in the beam of light blessings that have lain dormant probably throughout all previous time. And, as already stated, we have not found out yet all that may be known about, or all that may be contained in, a beam of light. For a certainty we have not found out much about the ether. But what little is known leads us to expect great things in the near future. By it we may yet understand a great deal more of the mysteries of gravitation and cohesion and obtain clear perceptions of the causes of the phenomena that are now very puzzling to us.

The ether conveys energy from the sun in the form of waves. These waves vary in length. To one set we give the name of *light*, and the eye is adapted for the appreciation of those waves. The surface of the body appreciates or feels other waves, to which we give the name of *heat*. Other waves are detected by delicate instruments, and to them we give the names of *electricity* and *magnetism*. As the eye receives light, so, Lord Kelvin says, the delicate coherer of Branly has an "electric eye," in that it is sensitive to electric waves of the Hertzian series. We speak nowadays of energy taking on the form of waves, and though electric currents are said to "flow" along wires, the expression is hardly accurate enough, as it flows in the medium surrounding the wire.

Although there is such a wide difference in rapidity between waves in air and those in the ether, there is a certain parallelism in their requirements and their behavior; so much so that for purposes of practical demonstration we use experiments with waves of air to illustrate those in the ether; hence the same terms are applied in each case.

This brings us to the law of sympathy, or "syntony," for us to understand which, as it is applied to wireless telegraphy, we must see its bearing upon musical instruments and in fact

upon anything that can be made to vibrate. It is well known to musicians that if a violin and a piano be in the same room, and if they are tuned to each other, as if about to be used in a duet, a note sounded on the violin will find a response in the piano, if the dampers be raised from the strings by putting down the pedal. It is useless to try to hear any result without previously tuning the violin.

In all wireless work or experiments carried out a system of " tuning " must be resorted to in order to establish perfect unison between the receiving apparatus and the transmitter. Yet the tuning does not refer to " sound " at all. The sympathy cannot exist between the two main parts of the apparatus when removed far from each other unless one be tuned to the other.

Before proceeding with a demonstration of the wireless telegraph instruments, an explanation here will assist us to understand it more clearly. Wireless telegraph is much more simple than is ordinarily supposed. The layman and the business man give the subject little thought or attention. It is my intention to briefly explain the subject as it presents itself, as free from technical language as possible.

The method of sending wireless messages is very much like the transmission of sound. In sound, the human voice, or whatever makes the sound, sets up vibrations in the air, which are carried in a wavelike motion until they strike the ear. The voice, or whatever makes the sound, corresponds to the transmitting instrument in wireless telegraph and the ear to the receiving instrument in wireless telegraph. The main difference between the two is that in the one the vibrations are set up in the air instead of in the ether. Ether, as I explained a few moments ago, is believed to fill all space and to lie around the smallest atom or molecule in any substance. Accordingly, sound in ether travels in wavelike motion, going through solid substances; and thus wireless telegraph messages can be sent through brick walls, etc. In wireless telegraph it is necessary to set up vibrations in ether in sufficient quantity and to provide a wireless receiver sensitive enough to record the vibrations. When a violin string gives out a note it vibrates back and forth, causing the air to vibrate to the same wave-motion.

In transmitting a wireless message, an electric condenser is made to discharge, oscillating back and forth many thousand times per second across a small air gap. The vibrations in ether thus produced travel in all directions from the aërial wire attached to the sending instrument and supported by the verti-

cal mast at the transmitting station, and some of them will impinge upon the corresponding antennæ wires connecting the receiving instrument at the receiving station. Since the receiving wires are good conductors, a number of these ether waves, called electric waves, will be collected and led down to the receiving instrument somewhat the same as with the human ear, which collects the air vibrations and carries them down to the ear drum.

When the electric wave impinges upon the vertical antennæ wire and reaches the Clark Wireless Telegraph receiving instrument known as a detector, the effect is to vary the sensitive electrical resistance in the local circuit which contains the detector. This causes a disturbance or sound in the receiver connected in the receiving circuit. The electric waves in the ether continue to come into the receiver, traveling at the rate of 186 000 miles per second, as long as the operator at the transmitting station holds his transmitting key down, and just so long a sound is heard by the receiving operator, who takes down the message in dots and dashes of the Morse telegraph alphabet just as fast as they are sent by the transmitting operator, the receiver responding automatically in the Clark Wireless Telegraph System, always in readiness for the next dot and dash.

It is this automatic feature which gives the Clark Wireless Telegraph the same speed as the wire telegraph and this is one of the chief points of distinction that places the Clark Wireless Telegraph System above all other foreign systems which are not automatic, but which are mechanical in action and are limited to one third the speed of the sensitive Clark responder. The Clark receiver is superior in freedom from local disturbances and is always reliable. Only with the sensitive Clark responder has it become possible to establish long-distance wireless telegraph communication between Detroit, Mich.; Buffalo, N. Y.; Cleveland, Ohio; Toledo, Ohio, and Port Huron, Mich., when using a very small power at the transmitting end for overland work.

Demonstration.

[In the first demonstration Mr. Clark showed the operating of a small portable receiver and transmitter, the ringing of a signal bell, the automatic recording of signals on tape machine, the starting and the stopping of small motor. Each part of the apparatus was explained in detail and was passed around to the members of the society to inspect. Mr. Clark explained their respective functions in the operation of the wireless machines, etc.

A 1 kw. rotary generator was then placed in operation and was connected to the 110 volts direct current. The alternating end was connected to the transmitting transformer with the shunt circuit across the spark-gap, consisting of inductance and a plate glass condenser, the inductance forming the primary of the oscillating transformer. This particular set of instruments had been used on the steamer *Western States* during the season and had given good results to the talking distance of 180 miles, using a wave length of 425 meters.

At this point of demonstration the room was darkened and Mr. Clark proceeded to show how this wave-length was measured on wireless telegraph and how the various stations are adjusted for different wave-lengths and how the tuning is accomplished on wireless stations by changing the inductance or capacity. Mr. Clark showed on this same set of transmitting instruments the changing of capacity and inductance so that the wave-length was increased from 425 meters to 750 meters. The aërial capacity consists of No. 8 B. & S. wire made up of 7 strands No. 22. This bare aërial wire was spread out in the laboratory room to the distance of 150 ft. and radiation was plainly seen to be very powerful.

Mr. Clark explained the construction of the wave meter, consisting of sliding tube condensers arranged to be joined in series or multiple series with variable inductance coil. The coil and condenser capacity were so arranged and connected electrically together that by the simple movement of the adjustment screw variations were simultaneous, the capacity of the condenser and the turns in the induction coil being in the same proportion. With the adjustment of a dial or scale placed above the condenser capacity and inductance coil one was able to read off the wave-lengths in meters and the wave-lengths in feet, as well as the oscillating constant, — the term "oscillating constant" signifying the square root of the product of the numbers denoting the capacity of the condensers reckoned in microfarads and the inductance in centimeters.

A general debate and discussion took place. Many questions were asked relating to the tuning and interference and to the amount of secrecy that might be obtained on the station. Mr. Duffield asked whether Buffalo station and Port Huron station could work at the same time that Detroit and Cleveland were working, and so on. Mr. Clark explained that in commercial work this had been done during the past season.

Colonel Davis asked whether, when the Soo station was working, it would be possible to talk with Duluth or Buffalo and Cleveland, and whether at the time that they were talking it would interfere with other stations or whether the other stations could be talking with each other at that time. Mr. Clark explained that as Detroit station had only a 5 kw. and Toledo a 2 kw. machine, Port Huron having a 10 kw. and Buffalo a 15 kw. and Cleveland a 10 kw., all these stations were arranged for different wave-lengths, and that in transmission and in receiving,

while the Soo with a 25 kw. machine should be sending messages to Buffalo or to Duluth, the stations at Detroit and Toledo could be working right along on shorter wave-lengths and there would be no interference.

Mr. Clark showed a map of the Great Lakes showing all the various stations and the zone in which each station was working, and he showed some of the high-frequency discharge and oscillations that took place on a high-tension 10 kw. station.]

Wireless Telegraph Work in Connection with the Marine Interests on the Great Lakes during the Season of 1907.

The stations of the Clark Wireless System opened early in March for the season of 1907. There were but two stations in operation at this time, one located at Detroit, Mich., and the other at Cleveland, Ohio. Early in the month of May another station was placed in operation at Port Huron, Mich. In August a fourth station was placed in operation at Buffalo, N. Y., and in September a fifth station was placed in operation at Toledo, Ohio, making a total of five wireless telegraph stations, bringing Buffalo, N. Y.; Cleveland, Ohio; Toledo, Ohio; Detroit, Mich., and Port Huron, Mich., into wireless communication.

Detroit, as is well known, is the point on the Great Lakes at which vessel owners usually intercept their vessels with messages if the port of consignment of cargo has been changed since the vessel left the head of the lakes; and as vessels frequently leave the head of the lakes without the knowledge of their port of destination, this was communicated to them by the Clark Wireless System on passing Detroit. So efficient was the wireless service in this, that, during the season of 1907, over 23 000 vessels' orders were transmitted by the Clark Wireless service between Cleveland, Ohio; Buffalo, N. Y., and Detroit, Mich.

Port Huron, Mich., as a point of passage, is of great value to vessel owners, and it was from this station that the reports of vessel passages were flashed into Cleveland, Buffalo, Toledo and Detroit. This gave the vessel owners ample time to formulate their dock orders before the vessel reached Detroit. It usually takes four to five hours to make the passage in the river from Port Huron to Detroit. The Clark Wireless Telegraph station at Port Huron reported over 25 000 boat passages during the season of 1907.

Beginning with the opening of navigation, the Clark Wireless Telegraph Company began the work of soliciting the telegraph business of the bulk freight owners from many of the

large marine interests on the Great Lakes. These interests combined represent some 320 fleets and over 1 000 vessels. The telegraph work consisted of reporting boat passages, orders, etc., from Port Huron and Detroit to the owners' and managers' offices in Cleveland, Toledo and Buffalo, and in receiving in reply messages and orders for the captains of the boats as to the destination for the vessel to go with her cargo; also furnishing the Cleveland office with all the up-and-down passages at Port Huron station. These were transmitted twice daily. The passages up to 8.00 o'clock in the morning were sent in at 8.30 A.M., and the passages up to 1.30 in the afternoon were sent in at 2.30 P.M. The vessel owners were able to formulate the docking destination orders before the vessels reached Detroit from these reports. In many instances the vessel orders and destination orders were given for the vessel on passing at Detroit and the destination changed again before the vessel passed the Lime Kiln Crossing. In many cases this could not have been accomplished by wire telegraph or even long-distance telephone, the Cleveland station operator and Detroit station operator transmitting and delivering some of these rush message orders in less than three minutes. A total of nearly 70 000 messages was handled during the season of 1907 for marine interests by the Clark Wireless Telegraph System. Had the five stations been in operation with the opening of navigation the number of messages handled by the stations would have been more than doubled for the season. The stations were operated for the entire season without delays or serious interruption.

The stations were in charge of men who had received some training in wireless telegraph work at the company's shop. They also had had some telegraph experience with the Western Union or Postal Telegraph companies in commercial work; without this previous experience they could not have handled the work so rapidly. When we consider that with comparatively new men on some of the stations — this being their first year in wireless work — this system of stations has been able to do this large volume of telegraph business, it speaks well for the men who had charge of the wireless telegraph work.

The stations at times were extremely busy and kept the operators on the jump. The telegraph strike of the wire telegraph operators in the month of August was cause for the immediate use of the Clark Wireless System by many commercial firms outside of the marine interests, and some 2 000 large business houses located in Detroit, Cleveland, Port Huron and

Buffalo took advantage of this system of communication; also many press dispatches were handled daily. The business firms and individuals that tried the wireless service remained with the Clark Company as customers when they found that the service was much quicker and just as reliable as the wire telegraph.

During the season of navigation the stations handled many messages from the stations to boats and from the boats to the stations, for passengers on the steamship lines which carried wireless equipment. Also reporting of the passenger boats as to their docking time and reporting of the cargo to the dock foreman and superintendent from four to five hours in advance of the steamer's reaching the dock was valuable information and was the means of handling the freight on arrival of the boat more systematically and rapidly; also during certain portions of the season, both in spring and autumn, the heavy fogs usually tying up all boats on the rivers and delaying them from three to five and six hours, wireless telegraph service proved of the greatest value.

The stations were kept open for twenty-four hours' service daily, but the night work this season proved very light, few messages being sent or received after the hour of 9.00 P.M., the operators merely sitting in circuit to receive a call or warning in case of accident to any of the boats carrying wireless equipment. With only a few boats equipped this night work did not pay, but with a larger number of boats carrying wireless equipment and paying for this service, a more favorable showing could be made. An increase is looked for from this source.

As for the outlook for profit-paying business from the first year of operation with only five stations, covering but a small portion of the lower part of the Great Lakes, the revenue so far derived was very gratifying and encouraging. The gross fixed expenses per month on each station for twenty-four hours of operation, which includes salary to all operators, messengers, power, light and miscellaneous, amount to $350; on 5 and 10 kw. stations, with each station handling 150 messages daily at a rate of 25 cents each, the earning on each station would amount to $975 per month of 26 days. Giving all the five stations the full number of messages daily which they could handle with practically no increase in the operating expenses and carrying work on for the entire season, the gross earning would amount to $48 750.

With an extension of the wireless telegraph system over

all the Great Lakes territory, with say twenty stations in operation, which would greatly increase the number of calls per station, and covering a much larger territory, with a larger increase in customers to each station, the gross earning power for the twenty stations per year would be $194 000. The maintenance cost is very low as compared with maintenance of wire telegraph with poles, etc.

Over a hundred of the men who have the management of affairs for the large marine interests on the Great Lakes have been talked with, and all say, " Without question the Clark Wireless service has proven the most perfect telegraphic communication ever furnished in this country." The Clark Wireless Telegraph Company has had a hard fight to gain a foothold on the Great Lakes and the work has just commenced. Public sentiment is to-day quite favorable. The straight push ahead policy followed by the management has won the hearty and highest respect of all the men connected with the large marine interests on the Great Lakes, and hundreds of others who have used the Clark service have learned to know its value.

The engineering and scientific ends are successful. The organization of the commercial end will have to be perfected before we can hope to handle all the business that the system of stations can take care of. We have made a good start and shall work up slowly but surely.

Wireless Telephone.

The success attained in the wireless telegraph field has long kept awake the hope of a practical realization of wireless telephone, but as long as the violent jerky spark as used in wireless telegraph was the only source, the fulfillment of the hope was not to be thought of. While the oscillating discharge was suitable and adaptable for wireless telegraph, it was not sufficient for the delicate telephonic transmission of intelligence. In wireless telephone we need a steady continuous undamped oscillation of high-frequency waves.

Prof. Elihu Thompson recorded, some ten years ago, the peculiar phenomenon that a direct current arc lamp light produces high-frequency alternating currents by shunting the arc with a circuit containing a suitable condenser and inductance, and later the properties of the singing arc were investigated by Duddell. In the shunt circuit, if we employ suitable condensers for capacities, we may be able to produce frequency from a few hundred up to hundreds of thousands of cycles per second,

whereas in a generator set for ordinary alternating current a fixed frequency only is attained. We must maintain vibrations in wireless telephone communication corresponding to the human voice, averaging five hundred per second to twenty thousand per second for the overtones.

Experimental results were obtained along this line first by Simons in wireless telephone on speaking arc experiments and later by Poulsen, the Danish electrician. From these small beginnings the wireless telephone has gradually developed into a more commercial and dependable instrument, and by a series of careful tests and arrangements we now are able to produce a continuous undamped oscillation to record all speech and sound or tones produced in the transmitter.

At present there are several methods of producing the undamped oscillation. I am now working with a multiple subdivided arc lamp, each lamp or arc occurring between cooled electrodes. The positive electrode is of copper and is fitted to a brass or copper tubing and this tubing is filled with water, the negative terminal being carbon. In forming the arc between the hollow surfaces of the copper electrodes and the carbon there is very little regulation required. The copper does not burn away and the carbon burns very slowly.

With a current of 3.5 amperes at 220 volts, or 1.5 amperes at 440 volts, a talking distance of from 5 to 15 miles can be reached.

The results so far obtained have been very satisfactory. Labor and time have been put in on this work, etc., each day, with better results always looked for, and it is quite a fine piece of work and requires careful adjustment to bring the receiver and transmitter into tune for talking. The capacity of the aërial wire at both stations requires careful adjustment and displacement in order to bring them in resonance. There is no question in my mind but that wireless telephone communication will be obtained up to one hundred miles or a longer distance in the near future.

Noticeable features are the absence of any capacity effect and that the tones of the voice are very perfect, no telephone noise being recorded.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by May 15, 1908, for publication in a subsequent number of the JOURNAL.]

THE WEALTH AND PROSPECTIVE DEVELOPMENT OF THE WEST COAST OF SOUTH AMERICA.

By Francis W. Blackford, Member of the Montana Society of Engineers.

[Read before the Society at its Twenty-first Annual Meeting, at Bozeman, January 11, 1908.]

This is not a technical paper, but one written at the request of President Kinney for something of interest to read to the Society at its annual meeting. I spent a little more than three years in professional work in Peru, as chief engineer of the Cerro de Pasco Mining Company; and chief engineer, and a part of the time superintendent, of the Cerro de Pasco Railway Company. I had charge of the construction of the railway from the beginning of the surveys to its completion, and the engineering work and surveying in and about the mines for over three years. During the period of my residence my time was too fully occupied to permit of much travel or the gathering of statistics, but I gained some general knowledge from observation, reading and intercourse with others that should be of interest to engineers, and possibly of profit.

Conditions in foreign countries are different from those at home, and the roseate hues which, in the imagination, surround far distant places are often dispelled by actual contact. We find that there are better opportunities overlooked at our own door. One of my clients once remarked: "I consider your services quite as valuable if you keep me out of bad things as if you put me into good ones."

The legitimate work of an engineer is the investigation of proposed undertakings, to see and weigh the bad as well as the good points and present them to his client in logical and comprehensive form. He wants facts, not theories, and conclusions drawn from facts. It has been my aim in this paper to point out some of the features and difficulties of work in a foreign country which were brought out prominently by my experience.

At the time of the Spanish conquest most of the west coast of South America was called *Peru*. The civilization found there was that of the *Incas*, which was similar to that of the Aztecs in the valley of Mexico, these two having the highest order of

civilization found on the western continent. The monarchy was absolute, and the ruler was called the "Inca." His country extended from somewhere north of Quito, now in Ecuador, to a point in what is now Bolivia. There were two capitals: Quito in the north, and Cuzco in the south. Following the conquest, stories were prevalent throughout western Europe of the great riches of Peru. Its name was a synonym of wealth, and the halo of romance that surrounded it has remained, in a measure, to the present day.

The story of the room full of gold as a ransom for the life of Atahualpa, the last Inca, and the subsequent yield of the mines of gold and silver worked by the conquerors, is doubtless responsible for the exaggerated idea of the wealth of the country. The gold to fill the room up to the height of the head of the conqueror — six feet one (as evidenced by the well-preserved remains of Francisco Pizarro, now in a glass case in the cathedral in Lima) — was gathered from all parts of the country, and it was only after much time and considerable difficulty that the subjects of the Inca were able to collect the amount imposed by the conqueror. With commendable generosity he permitted them to pile the gold ornaments at random in the room, not requiring them to be placed so as to occupy the least space.

After the room was full to the point stipulated for the ransom, Pizarro killed the Inca, or caused him to be killed. This act showed to the world the character of the early Spanish explorers and conquerors. They ruthlessly murdered those who resisted, and made slaves of the remainder.

Peru is not a rich country, never has been, and probably never will be. Wealth comes from natural resources developed by intelligent labor. Peru has neither of these, and the same may be said of nearly all of the west coast of South America, from Panama to Cape Horn.

From a point near the south boundary of Ecuador to Valparaiso, 33° south latitude, a distance of about 2 300 miles, the parts bordering on the sea are absolutely barren; it never rains there. Crops are grown by irrigation, but only in the valleys of the streams which come down from the mountains. These streams are not large because the summit of the mountains is seldom more than 60 miles from the coast. The rainfall west of the summit which feeds these streams is often torrential and destructive during the wet season, at altitudes above 6 000 ft., but those are not conditions favorable to irrigation, and as the valleys are narrow, the agricultural products are not great.

There is practically no timber, not even enough to furnish fuel for domestic use, anywhere between the coast line and a point about 100 miles east of the summit of the mountains. Within this area there is copper, silver, gold and some coal, but with the exception of the mines of silver and copper at Cerro de Pasco, there are none of great magnitude in Peru. The mountains are extremely rough and broken and reach such great altitude that prospecting is difficult, and even when mineral is discovered, it must be very rich to justify the time and money necessary either to transport or to work it. The passes in the Andes in all of this district have from 10 000 to 17 000 ft. altitude, and most of them exceed 13 000 ft.

There is some coal in the country. I examined with considerable care two fields, one on the east side of the range and one on the west side. There were many croppings with a considerable showing in places, but the strata were so twisted and faulted that I found it impossible to trace the veins for any distance, and failed to find any body of coal that appeared to be continuous or gave promise of profitable returns to a commercial enterprise.

There were practically no highways in the country, only trails, and those mostly bad and selected without much regard for rise and fall. The best trail I saw was an old Inca trail, probably a part of the great road from Quito to Cuzco, described by Prescott (description copied by me into a paper on "Highways and Street Pavement," read before this Society in 1898). I think Peru has no laws for the construction and maintenance of highways; if it has, they are not enforced and the trails are in a frightful condition.

The transportation problem is a serious impediment to the development of any part of this section of country. Except the two railways hereafter mentioned there are no means of communication other than pack trails; therefore the development of any mines or agricultural district requires the time and money necessary to construct wagon roads or railways. The mines at Cerro de Pasco had been worked for two hundred and fifty years and are said to have produced more than 1 000 000 000 oz. of silver, yet there was never anything but a pack trail from there to Lima, a distance of nearly 200 miles. After the completion of the Oroya Railway, in 1894, a wagon road was constructed a part of the way to Oroya, its terminus, and a pack trail the remainder. This was done by private subscription among the mine owners. This was followed by the construction of the Cerro de Pasco Railway from Oroya to Cerro de Pasco in 1903–4, and short branches aggregating 112 miles.

Another feature very important is the transportation of skilled labor. Such labor has to be paid its time and expenses from the place where it is hired. To reach there from North America or Europe takes about a month. Count this twice, and allow two weeks for acclimating, and you have lost a little over 10 per cent. of the time of any employee engaged for a two-year period. There is also more or less going back and forth by the higher salaried men, with the attending expense and loss of time. The manager of one of the Peruvian enterprises very aptly remarked that " one might think this an enterprise for the promotion of foreign travel."

The wages for skilled labor are high. Unless you pay more than the man gets at home he will not go. Many that go are unsatisfactory or incompetent, or become dissatisfied and leave. The supply, in consequence, is likely to be short, the discipline less exacting and the services less efficient and productive. The expense and annoyance from this source are very great.

Common labor in Peru is cheap and fairly good, but scarce. The number of persons who gain a livelihood by this means is small. For our work, the enganching process was used. For a consideration of ten cents for each day's labor, paid to a local officer, priest or prominent citizen, he would gather together laborers from the little farms or large ranches and engage them for from two to six weeks' service. This labor often came long distances, as much as 100 miles. The system is more or less feudal. The laborers usually came unwillingly and left as soon as their time was up, but it was the only way to get them; except at the instance and under the direction of those named, they would not come at all, nor could we ever get this class of labor either at planting or harvest time. They live at out-of-the-way places in a very primitive fashion, and produce practically all they need. We paid for common labor one Peruvian *sol* per day, equivalent to 48.5 cents United States money, and 10 cents, Peruvian, to the *enganchador*. At Cerro de Pasco and round about there were regular miners, laborers and packers, but only sufficient for the work going on there.

I had, at one time, a commission from the President of Peru to make a reconnoissance for a railway from Oroya, or from a point between there and Cerro de Pasco, to a point at or near the head of navigation for steamboats on the Amazon, or its tributaries, these reconnoissances to be followed by surveys. In pursuance of that plan instruments and equipment for two locating parties were purchased. When I was ready to start,

however, the funds to defray the expenses were not available, and several months afterward, when they were, my duties with the Cerro de Pasco were such that I could not go, and later on, owing to political changes, the project, much to my disappointment, was abandoned.

In the meantime, however, I had gathered all available information about the geography, topography, products, etc., of the country, and was surprised to find how little was known. Various travelers, including priests, rubber hunters, prospectors and others, had seen each a part of the country, but the knowledge thus obtained was not classified and really was of little value. Small steamboats in the rubber trade ply the river and its tributaries above Iquitos, which is the head of navigation on the Amazon for ocean steamers. Those engaged in that trade say the valleys are fertile and not unhealthy and that the forests in some districts are infested by cannibals who use poisoned arrows. It is not likely, therefore, that they went far from the river, or explored to any great extent the tributaries where the natives were bad.

The river valleys in these sections are covered with a dense forest. According to reports received, the rivers were navigable to about an altitude of 2 500 ft., but there was very little information in the possession of the government as to where the head of navigation actually is or the most practical way to get to it. I believe from reports that the forests begin in some sections at about 6 000 ft. altitude and continue eastward; that they are dense tropical forests containing more or less timber of commercial value, but nobody with whom I talked had very exact knowledge. One of the engineers of the Cerro de Pasco Company made a reconnoissance of the mountainous district east of the main range for two or three hundred miles north of Cerro de Pasco. He said that the country was terribly rough and broken, sparsely inhabited and barren; that at times he could not get fuel to cook his food. He described the country as similar to that which I had seen 40 to 50 miles north of Cerro de Pasco.

This was built on stupendous proportions and was of incredible roughness. It afforded, however, a view of grandeur and magnificence seldom seen. The peaks of the main range have an altitude of more than 20 000 ft. and the sides are covered with glaciers of great thickness, — judging from appearances lower down I should say at least 1 000 ft. I crossed the range at two passes to the south of these high peaks and boiled water to get the altitude. None of our aneroids was reliable above 13 000

ft., and many of them would not work at all, notwithstanding they were rated for 20 000 ft. These passes were about 16 500 ft. A short distance above them the glaciers began; in fact, I went up to a glacier and broke off a piece of ice to melt for the boiling water. From this altitude the glaciers were not continuous, but lay in patches not confined to ravines, but plastered in places to the sides of the almost vertical slopes in a most unaccountable manner and looking as if they might slide off at any moment. Much to my regret I never had time to visit any of the great ice fields, or the termini of the great glaciers which came down from the high peaks. At that latitude, 12° south, on the main range they begin at about 16 000, and at from 17 000 to 18 000 pretty well cover the mountains and continue to the top, excepting on exposed spots, where the wind blows the snow away. On a secondary range of peaks, lying about 75 miles to the east of the main range, the line seemed to be lower, and doubtless was, but I never was able to go over there to investigate. From the higher points near Cerro de Pasco on a clear day those glittering monsters were very impressive, grand, solemn, silent and untrod. The eastern peaks, though lower than those of the main range, were seldom seen, being enveloped in clouds except in the clearest weather. The altitude of Cerro de Pasco is 14 200 ft. A thermometer in the shade there would range from about 16 to 60 degrees fahr. in 24 hours.

From my observation, and information received from other sources, I should say that in all that stretch of country from Ecuador nearly to Santiago, Chili, there are only a few comparatively smooth spots, one being near Cuzco, another near Cerro de Pasco, another near Quito. All the remainder is a mountainous country, extremely rough and broken, semi-barren, and much of it high and covered with glaciers. On the west side, from a short distance below the summit to the sea, it is without trees or grass, and practically without rain. From the summit of the mountains eastward about 100 miles it is likewise very rough and broken and practically without timber, but bountifully supplied with rain during the rainy season, a fair grazing country, and susceptible of agriculture in a small way, sufficient to supply the needs of the native population. Beyond this point, and below about 6 000 ft. altitude, the country is tropical and covered with forests; at about 2 500 ft. the rivers are navigable for small boats. Away from the rivers little is known of the country in the lower altitudes.

Under such conditions, how can the west part of South

American develop into a rich or productive country, or develop rapidly?

The Pan-American Railway in these parts is a dream of dreamers that doubtless will never be realized. The country in the river valleys east of the mountains, if it is rich and habitable, would get an outlet and a market for its products eastward and northward on the lines of drainage. Such natural barriers have always separated nations and diverted trade. Transportation enterprises are not seeking lines involving summits of 16 000 ft.

The Oroya Railway is ocular proof of the difficulties of such obstacles. It has been described so often that I shall say no more here than that it starts from Callao, the seaport 7 miles from Lima, and stops at Oroya on the east side of the Andes, at an altitude of 12 400 ft., and has a total length of 130 miles. It crosses the summit at Galera tunnel, where the grade line has an altitude of 15 665 ft. The gradient is supposed to be 4 per cent., but in places it is now 4.5. It is standard gage and has 16° maximum curves. It follows up the valley of the river Rimac, and overcomes the altitude by 11 switchbacks and many turns in the Rimac valley or its tributaries, these turns involving tunnels or heavy cutting and filling. The line is on the mountain side most of the way and shows very clever engineering, some of the greatest of its kind in the world. There are some 58 tunnels and many high and expensive bridges. Four engineers prominent in the West, and some of them well known in Butte, *viz.*, Messrs. Bogue, Briggs, Maxwell and McCartney, spent several years on this work. During the seventies, Henry Meigs, a Californian, promoted such improvements in Peru, using the credit of the government, and obtained about £12 000 000 sterling. This was all spent, most of it in railway construction, the result being two unfinished standard gage railways part of the way across the mountains, one terminating at the Port of Mollendo, the other at Callao, as aforesaid. The Oroya Railway runs two passenger trains each way a week, and as many freight trains as are necessary to do the business. When I went there in 1901 it was one a day, consisting of three cars, or about 50 tons net maximum load, taking two days to come up. This business, however, was greatly increased later, hauling the construction materials and supplies for the Cerro de Pasco Company, at $15.00 United States currency per ton.

The road is subjected to serious landslides which interrupt traffic for weeks at a time. Prior to 1901 it had never paid more than operating expenses and much of the time not that. Of the

Mollendo road I know but little. Its financial condition is much the same as the Oroya Railway, but its cost was less.

Of the Peruvians, the descendants of the Incas, as well as the Mexicans, the descendants of the Aztecs, either of pure blood or mixed with Spanish or other blood, I wish to say that I consider them equal in natural intelligence to any people on the earth. Their opportunities have been limited and they have had training only in a few lines, but they are good workers, with keen natural intelligence that responds to instruction as quickly and effectually as any I have ever seen. In the art of cutting and laying stone, carpentry, building in general, blacksmithing, mining, packing and driving animals, and such arts as they have been trained to, they show great skill. I would put the native Cerro de Pasca (Peruvian) or the native Guanajuato (Mexican) miner against the best that Butte could produce and expect to get as good results (and at the present time, at about one seventh the cost).

The people of Peru are naturally as intelligent as those of other parts of the earth, but they are lacking in training, especially in the mechanical arts. They do not know how to do things, therefore their labor does not produce much wealth. Class distinctions are closely drawn; we have the man who works with his hands and the man who does not, and the man who does not has but little knowledge to direct the man who does. There are, of course, exceptions to these generalities, but they are in the main true.

Very little attention is paid to the details of agriculture or stock raising. The vegetables and fruits are all run down and the yield is small. The males of all domestic animals are permitted to run without selection with the flocks or herds and, as a consequence, the stock is run down; fowl, the same. There are no fruits except some tropical varieties; notwithstanding there is variety enough in the climate, due to difference in altitude, to produce apples, peaches and other temperate zone fruits. Very little attention is paid to the art of cooking, and as the material is bad and variety limited, the food is bad — the worst I have ever eaten.

The Chileños are more progressive than the Peruvians, and, indeed, more progressive than any people south of Mexico — probably south of the United States. They have paid more attention to education, have established agricultural schools and experiment stations, and have encouraged the mining of copper nitrate and coal. The mining is carried on mostly by foreigners.

Southward from a point a few hundred miles north of Valparaiso there is some rain on the west coast. This gradually increases and becomes very heavy to the southward, but the country around Valparaiso and between there and Santiago is semi-arid and agriculture is carried on only by irrigation in the valleys. The stock is good and the fruits and vegetables compare very favorably with those of the United States and are distinctly temperate zone products.

There are a number of railways of standard gage in fair condition. One railway is projected to connect with the Argentine system. The termini of the lines were about 25 miles apart when I crossed over in January, 1905, and construction work was going on slowly on the Chilean side. The plan contemplates a long tunnel. The altitude of the pass is a little over 13 000 ft. I could not learn much about the plans, but should judge from the topography that a 2-mile tunnel would not reduce the summit altitude more than 1 000 ft.

The main railway system in Chili has a standard gage, that of Argentine a 6-ft. gage. The connecting link, which is some 200 miles in length, is a meter gage. The maximum grade seemed to be about 3 per cent., except where there was a rack and cog. There it was anything between that and 10 per cent. There was a rack fastened to the ties in the center and extending 3 or 4 in. above the rail, and a cog on the driving wheel. The engagement was made very readily without stopping, and the system seemed to work well. Transcontinental freight will have to change bulk twice by this route.

When I made the trip from Valparaiso to Buenos Aires, it was as follows: 5 hr. by standard gage, 5 hr. by meter gage, stop at an inn 8 hr., diligence with 4 horses abreast 6 hr., saddle mule 3 hr., meter gage railway 7 hr., then 6-ft.gage express train (sleeping and dining-cars) 24 hr.

But to get back to my subject on the west side of the mountains and conclude:

I should say that Chili has more agricultural and mineral wealth than Peru, but the whole west coast of South America, as compared with the fertile and otherwise richly endowed spots on the earth, such as Europe, China, India and the United States, is of very little importance in the world's commerce and affairs and does not offer quick or profitable returns for large enterprises.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by May 15, 1908, for publication in a subsequent number of the JOURNAL.]

THE RIGHT-OF-WAY OF THE GREAT LAKES.

By F. C. Shenehon, Member of the Detroit Engineering Society.

[Read before the Society, January 16, 1908.]

Mr. President, Gentlemen: Any device for transporting passengers, commodities or freight has, of necessity, two essential correlative parts, — the carrier and the track. In the case of a water route, the tracks may be infinite in number, and the locus of these tracks may be called, for lack of a better term, the *right-of-way*, after the analogy of a railroad. The Great Lakes, viewed as the right-of-way of a transportation system, is my subject to-night.

There are a great many structures on the Lakes, magnificent ship locks, canals and canalized rivers, splendid breakwaters and harbors, docks and terminal devices for the rapid handling of cargoes. The right-of-way is planted with lights and buoys to guide the vessels, and the vessels themselves and the commerce of the Lakes are worthy of many papers. It is hoped the discussion will develop some things concerning these, but in *this* paper it is purposed to deal with the naked right-of-way of the Great Lakes — the basin, the water, the property and its engineering administration — and to touch on some of its problems.

The total water area of the Great Lakes is 95 645 square miles, and this includes the interlake rivers and the St. Lawrence River so far as it marks the international boundary. Lake Superior, with its 32 060 square miles of surface, is a third of the whole; Michigan takes 23.3 per cent., Huron 24.3 per cent., Erie 11.1, and Ontario 7.8 per cent.

Nearly two thirds of this area, or about 62 000 square miles — which is roundly the area of the New England states — lies on the American side of the boundary.

The vitality of the Lakes comes from a watershed of 192 600 square miles; the whole drainage area — that is, watershed plus water surface — is 288 245 square miles. The surplusage of water which flows down the St. Lawrence River and ultimately debouches into the ocean is over 250 000 cu. ft. per second.

The mean surface of Lake Superior is 602.31 ft. above the level of mean tidewater in New York harbor. In St. Marys River a descent of 21 ft. is made, about 19 ft. of this being in

the rapids at Sault Ste. Marie. This brings us to Lake Huron. Out of this Lake Michigan opens through the level roadway of the Straits of Mackinac, and because these lakes are simply two lobes of one level body of water connected with a bypass, it is not uncommon to speak of them as a unit hydraulically —Lake Michigan-Huron.

From Lake Huron down to Lake Erie is two steps, one of $5\frac{3}{4}$ ft. in St. Clair River to Lake St. Clair, and a second of 3 ft. in the Detroit River to Lake Erie — still 572.60 ft. above the sea.

From Lake Erie to Lake Ontario the descent in the Niagara River is 326.42 ft., and 160 ft. is sheer fall over the Cataract.

The St. Lawrence River, during the 110 miles of its course as a boundary stream, makes a descent of 94 ft. from the level of Lake Ontario.

Summing up the several steps from Lake Superior down to St. Regis shows a total descent of 450 ft., with the river still 152 feet above the Atlantic Ocean.

Lake Superior has an axial length of 382 miles, with a maximum width of 160 miles, and depths as great as 1 000 ft.; Michigan is 345 miles long by 118 miles wide, with 870 ft. maximum depth; Huron, 265 miles long by 146 miles wide, with 750 ft. maximum depth; Erie, 250 miles long by 57 miles wide, with 210 ft. maximum depth; Ontario, 202 miles long by 53 miles wide, with 738 ft. maximum depth.

Now these great fresh-water basins differ from artificial reservoirs mainly in their splendid scale. Despite their bigness they are simply reservoirs, and to a considerable extent at the present time they are artificial reservoirs; that is, the natural surface levels have been changed — raised or lowered — by engineering works in the outflow rivers, or by the creation of artificial independent outlets. And these interferences with the surface levels exist on each of the lakes, and, except in the case of the Lake Superior compensating works, they were not intended to produce the effect which has come from them.

It is expected to show later that engineering works specifically designed to control the outflow and fix the lake surface levels at desirable stages must eventually supersede the present mongrel condition. By *mongrel* I mean neither purely natural nor purely artificial.

Well, each lake is impounded, and its level fixed, primarily by a natural barrier in the outlet. For Lake Superior, ledge rock — Potsdam sandstone — forms a dam, a submerged weir in St. Marys River. At the crest of the weir, which is at the head

of the rapids, the water runs crystalline clear over the clean ledge rock. I speak of this crystalline quality of the water not for picturesque effect, but because this very clearness of the swift water is an element in the permanence of the dam. The lake above is a settling basin, so the water rarely carries any sediment, and the dam is saved the fierce and incessant bombardment of minute particles characteristic of sedimentary streams. The downstream slope of this natural dam is rock in place strewn with glacial drift, forming the bed of the rapids — with a descent of 19 to 20 ft. in $\frac{3}{4}$ of a mile. The rapids at the "Soo" have the effect of a sheer fall, and backwater from Lake Huron has no retarding influence on the outflow of Lake Superior.

Lake Michigan-Huron is held primarily in check by a constricted outflow section at Port Huron, a *gut* over 60 ft. deep by 700 ft. wide, and this is reinforced by the inertia of the St. Clair and Detroit rivers. The hydraulic conditions existing in this wasteway are somewhat complicated. Considering each of the lake outflows, however elongated, as a submerged weir, the St. Clair-Detroit River weir has a downstream slope length of 85 miles. In spite of this great length, the efficiency of flow is affected by the tail water. That is, backwater from a high stage of Lake Erie at Amherstburg retards the outflow of Lake Huron at Port Huron. It is not difficult to credit this, because the fall between lakes is only $8\frac{3}{4}$ ft. That $8\frac{3}{4}$ ft. is the potential needed to maintain a certain volume of flow. Should Lake Erie rise 3 ft., only $5\frac{3}{4}$ ft. remains, and that $5\frac{3}{4}$ ft. of fall could hardly be expected to do the work accomplished by $8\frac{3}{4}$ ft. before.

Lake Erie is impounded primarily by a limestone bed rock ledge or submerged weir at Buffalo, but, as in the case of the St. Clair River, this is dependent for its efficiency on the inertia, resistance or backwater in the river below, reaching here for 20 miles to the rapids above the Cataract at Niagara Falls. The ledge rock at the head of these lower rapids, forming a second submerged weir, reinforces, by backwater effect, the initial submerged weir at the head of the river. As the river descent between these two weirs is but ten feet it is easy to understand the correlation of the weirs.

Lake Ontario finds the barrier which restrains it at the Galop Rapids, 67 miles down the St. Lawrence River, where a submerged weir of sandstone exists. From the point of view of hydraulics this 67 miles of placid river flowing leisurely through the Thousand Islands must be considered as an arm of the lake, even though in this reach a descent of two feet is made.

The Galop Rapids has a fall of eight feet in one mile, and the weir discharge is not affected by backwater in the lower river.

I have explained the construction of the waterways of the basins of the Lakes in some detail because the integrity and the betterment of the right-of-way hinges on them.

Now it has been estimated that if Chicago should be given 14 000 cu. ft. of water per second which she wants for the Drainage Canal, Lake Michigan-Huron, Lake Erie and Lake Ontario, and all the rivers from St. Marys below the locks, down into the St. Lawrence, would drop somewhere in the neighborhood of eight or nine inches. This eight or nine inches means much or little only as it scales on the measuring stick of dollars, and this leads to a brief discussion of the commercial use of these reservoirs and connecting rivers, which form the right-of-way of the Great Lakes.

You will remember that La Salle in 1679 built the *Griffon*, the first ship to sail Lake Erie, and that it shortly vanished into thin air. A part of the navigators of those days were missionaries interested in saving redskins; but some of them were more interested in saving beaver skins, and most of them had their hands full at times saving their own skins. These voyageurs, missionaries and fur traders, with their canoes and bateaux, had little thought of *aids to navigation*, yet at Sault Ste. Marie, on the Canadian side, just 110 years ago, they were building a lock to facilitate the climb of the rapids, and in 1850 a tramway portage was built on the American side. The authorized charge on this tramway for getting freight past the rapids was 5 cents a hundred pounds, or $100 per ton. While this charge as a mile-ton rate is more than 1 000 times that of average Lake freights rates at the present time, it was not for this reason solely, nor the delay, but because, in addition, vessels were needed on Lake Superior, that a ship lock was wanted at Sault Ste. Marie. The agitation for a ship lock preceded 1840, in an attempt to get from Congress a land grant to enable the state to build a lock. This land grant was secured in 1852, and the ship lock was completed in 1855, with chambers 70 by 350 ft.; the canal draft was fixed by the terms of the land grant at 12 feet.

The principle that the general government had any *right* to expend money on streams subject to interstate commerce was not entirely accepted even in 1855; but in 1856, under the somewhat facetiously accepted doctrine that the improvement of these channels would assist a naval movement, and could therefore be construed as a war measure, appropriations to secure 12-ft.

draft in St. Marys River were passed over President Pierce's veto. The opening of the lock at the "Soo," and this dredge work in St. Marys River, and that in St. Clair Flats, gave nominal 12-ft. navigation between Duluth, Chicago and Buffalo; and this dredge work in particular marks the full assumption by the general government of the burden of improving, maintaining and operating the right-of-way of the Lakes as an interstate highway. State sovereignty was more keenly felt in those days, when men who had known actual state independence were still alive; and it was only a few years before the Rebellion, a war in which *state rights* was the issue.

I am not sure that the relative activities and jurisdictions of the states and the nation in the waters of the Great Lakes are entirely clear. The general principle, however, as I understand it, is this. In Lake Huron, for instance, the state of Michigan extends out to the international boundary; the state holds the title to the submerged lands in fee; the nation, on the other hand, holds jurisdiction over these waters, from the meander line out, for purposes of navigation, and as a boundary stream or lake. The exact demarcation of the respective rights growing out of these overlapping jurisdictions is not always obvious. As an instance, at Niagara Falls a certain power company has claimed the right to divert water from the Niagara River under a New York state permit; and it has been argued likewise that the state of Illinois has the right to divert the water of Lake Michigan. The government, however, reserves the right of interference with the navigable integrity of interstate waters or of waters defining the national boundary, and this reservation has even a broader international signification.

An inland lake or river contained wholly in one state, with no navigable connection leading to a second state, is not an interstate waterway; and in such a case the general government has no jurisdiction whatever. Even federal laws regarding steamboat inspection do not apply.

It is not purposed to follow the history of the development of the artificial channels, or of the harbors of the Lake system. The locks at Sault Ste. Marie have, since 1855, set the drafts and limited the vessel dimensions. The steps are these: 1855, Old State Lock, 10-ft. drafts; 1881, Weitzel Lock, 14½-ft. drafts; 1896, Poe Lock, 20-ft.; some time in the next five years, Davis Lock, 24½ ft., or greater, drafts.

You will observe that the old state lock, which was built for 12-ft. navigation, shows only 10 ft. of draft in this series. If it

had been in existence during the past season it would have had little over 10 ft. on its lower sill, and this is because the Lakes were higher half a century ago.

Even prior to this state lock of 1855 vessels of 500 tons navigated precariously on 12-ft. drafts as far as the "Soo," and 12 ft. was available in some harbors; but when the lock was once built, that became the standard, channels and harbors worked to the lock draft, and vessels were built to fit these channels and harbors.

Later, the Weitzel Lock, built in 1881, for $14\frac{1}{2}$ ft. drafts, set harbor and channel depths; and in 1896, the Poe Lock, with 20 ft., became the standard for the channels connecting Duluth, Chicago and Buffalo, and this is in operation now, but with drafts little better than 19 feet.

Our President can speak with authority of the splendid works at the "Soo," and of the canalization of St. Marys River, and that of the St. Clair River as well; and Mr. Dixon with authority on the lower Detroit River, and Colonel Davis on both. These are the critical places in the navigation of the Lakes. For the most part artificial channels are at least 300 ft. wide, with greater width on curves. In rock cuttings, and where exposed to a seaway, they have at least a foot greater depth than elsewhere. Alternating channels, one for up-bound and one for down-bound boats, are replacing single constricted channels at the Neebish, at the Flats and in the Detroit River. The danger of blocking single channels by collisions has become too great and too costly, as a day's navigation of the Lakes is worth a quarter of a million of dollars in freight charges.

Taking the Detroit River traffic as $84\frac{1}{2}$ per cent. of the Lake tonnage, the blockading of the lower Detroit River, by sinking a vessel across the channel, would entail a loss of $200 000 a day, in addition to the loss to the damaged vessels. The alternating channel diminishes this great risk.

The commerce passing the "Soo" Locks, that up to the breaking out of the Civil War had shown a maximum of 153 721 net tons, has now, in 1907, grown to the great aggregate of 58 million tons, 377 times the volume of the ante-bellum commerce.

Estimating, by the ratio of 1906, between the traffic passing the "Soo" Locks and the total traffic, shows the domestic Lake commerce of 1907 to be 85 million net tons, having a valuation of 883 million dollars. The freight charges on this at 66 cents per ton amount to 56 million dollars.

Now, if the ore and coal and grain and lumber and other com-

modities transported on this right-of-way had been moved by rail, it would have cost not less than three times as much, and the saving in freight charges is, therefore, 112 million dollars for the year; and, as a penny *saved* is a penny *earned*, this 112 millions is the earning, the dividend, distributed to the people of the nation as stockholders in this coöperative transportation system.

At the present time our railroads are inadequate to the needs of shippers, even without the additional burden of the vast freight volume of the Lakes. James J. Hill is quoted as saying that in the past few years mileage of track has increased 22.7 per cent., and traffic 126.4 per cent. If the Lake Superior ores depended on rail shipment it is doubtful if the nation's supremacy in the world's steel industry would exist. You will remember in the cases in which Judge Landis inflicted the 29 million dollar fine, the published freight rate on oil was 18 cents, while the Standard Oil Company paid 6 cents. The advantage of the octopus of a freight rate of *one third the going rate* is the same advantage our steel industries enjoy — compared with their condition without the right-of-way of the Great Lakes.

Now this right-of-way, regarded as a *property*, has a certain value, and it will be of some service to approximate this, because on property worth a hundred dollars an acre you might be warranted in making certain expenditures for surveys or improvements not warranted on property worth one dollar an acre. If the government did not own the Lakes, and could not use them otherwise than by purchase, how much would it be warranted in paying for them? The government can borrow money at 2 per cent. Capitalizing the earning capacity of 112 millions at this rate shows a present value of 5 600 million dollars for the right-of-way. And the profits on this purchase price would come in with a ten per cent. annual increase of valuation, in the fisheries, in water powers and in such subsidiary uses as for parks, reservations, and for sanitation, as at Chicago.

There are about 40 million acres on our side of the boundary, and each acre is, therefore, worth $140, — which is more than the value of farm land in Michigan. As the United States government up to the present time has invested less than 100 million dollars in improvements on the Great Lakes, the total expenditure per acre is less than $2.50; and the present yearly earning capacity is about $2.80 an acre; so the *yearly earning* is in excess of the *total investment* in improvements. The surplus earnings of three or four years of the Great Lakes transportation system will pay

for the Panama Canal. It may be of interest to add that private and corporate interests are credited with a holding of about $150 000 000 in vessels and terminal facilities.

A right-of-way of such importance, such extent and such value, is worthy of a competent engineering organization to explore, improve, maintain and operate it. You are aware that all public works relating to navigation, including the Panama Canal, are in the hands of the Corps of Engineers of the army, under the big War Secretary Taft. I am not certain, however, that every one is familiar with the genesis of an Engineer Officer of the Corps. They are all West Pointers, and the top men of each class; sometimes the four top men; this year the nine top men. The second-best men may go into the artillery, the next into the cavalry, and the bulk into the infantry. The Engineer Officers are, therefore, picked men. After leaving the academy they take a couple of years in post-graduate work in engineering before entering active service. The Chief of Engineers has his headquarters at Washington, and is appointed by the President from among the ranking colonels.

For administrative purposes the Lakes are divided into seven geographical districts, each with an officer of the Corps of Engineers at its head, and these officers, as I have said, have charge of all river and harbor improvements and of the operations of all locks and canals.

Beginning at the east end, the first district, under Colonel Fisk, of Buffalo, includes the St. Lawrence River; all Lake Ontario harbors, including Charlotte and Oswego; Niagara River; and, on Lake Erie, Buffalo, Dunkirk and Erie harbors. The second district, under Colonel Townsend, of Cleveland, takes in all Lake Erie harbors west of Erie, including the important harbors at Conneaut, Ashtabula, Cleveland, Sandusky and Toledo. The third district, under Colonel Davis, of Detroit, includes the Detroit, St. Clair and St. Marys rivers, Lake St. Clair, and all Lake Huron harbors, including Cheboygan in the Straits of Mackinac. The big works at the "Soo" and the channels in Hay Lake and at the Neebish and in the lower Detroit River, make this district a heavy one. The fourth district, temporarily under Major Keller, with headquarters at Grand Rapids, has jurisdiction over the rivers and harbors on the east shore of Lake Michigan from Michigan City up. The fifth district, under Colonel Bixby, of Chicago, includes the important works in the south end of Lake Michigan and some of the rivers and canals extending inland. The sixth district, under Major Judson, of

Milwaukee, contains the rivers, harbors and canals on the west shore of Lake Michigan from Waukegan northward; and the seventh district, under Major Fitch, of Duluth, takes in all the rivers and harbors of Lake Superior.

Now these seven engineer districts are engaged mainly in work relating to artificial channels and terminals, — that is, to *rivers and harbors.* Outside of the rivers and harbors are the open lake areas, the big right-of-way of the Lakes, with its intricate mesh of vessel tracks. In these the United States Lake Survey works. It is the engineering staff-at-large, dealing with the lakes as a unit, as a single transportation system. While the District Engineer is concerned with the needs of his own district — and there is enough work in each district to keep an officer busy — the Lake Survey handles the large questions of Lake levels with a view to their regulation, all extended surveys, soundings and sweepings, all magnetic surveys for compass variations, all charting of the lakes, and systematic notices to mariners of changes affecting navigation, — in short, the things that concern the Lakes as a whole and are vital in the operation of this great transportation system. The jurisdiction of the Lake Survey corresponds to that of an eighth district extending over the whole Lake region, overlapping, embracing and coördinating with the seven other districts, and reaching into every river and harbor. But it has nothing to do with dredge work, it does not build locks or breakwaters. The Lake Survey is under Major Charles Keller, of the Corps of Engineers.

The officers of the Corps correspond to Chief Engineers in civil practice, and they are aided by civilians — in the highest rank called Assistant Engineers, with the prefix Principal for the ranking Assistant.

The government service is attractive on account of the magnitude of the works and problems. The work is larger than two by four.

Among the public works of the United States the Panama Canal ranks first in importance, New York Harbor second, and Detroit third. Our president is Principal Assistant Engineer of the Detroit office, and Mr. Dixon is in local charge of the six-million-dollar Detroit River improvements in the vicinity of Amherstburg.

The Lake Survey also has some big problems that are attractive. Of course the Lake Survey, because it covers seven engineer districts, ought to be more important than Panama, New York or Detroit, but I cannot convince some people that

this is so. However, it is important enough to warrant my saying something about it.

The Lake Survey began work in 1841, and, except for suspended animation for a single year, has existed ever since. A part of the time it has barely existed. It is rather remarkable that the concentration of energy and the straining of resources to meet the crisis of the War of the Rebellion did not interfere with the prosecution of the Lake Survey. On April 12, 1861, Fort Sumter was fired on. In the preceding March the Lake Survey appropriation was $75 000. The succeeding years show appropriations as follows:

1862	$105 000
1863	106 879
1864	100 000
1865	125 000

It may be that the surveys of the frontier had a military significance, growing out of the possibility of international complications.

In 1866, after the war was over, and the nation felt poor, the appropriation dropped to $50 000, but by 1868 it had grown to $152 500, and remained at a good figure until the winding up of surveys in the late seventies. Then the Survey slept on a trifling annuity of two or three thousand a year until 1889, when a mild eye-opener of $7 000 was received. By 1893, with the Poe Lock building at the "Soo," and deeper-draft navigation in sight, a $27 000 appropriation was made; by 1898 this was $28 000, and in 1900 it had grown to $78 000. From that on the renaissance has been in flower, with appropriations reaching as high as $150-000 a year. The present project contemplates an expenditure of $125 000 a year for twelve years — a million and a half in all.

The reason for the rebirth of the Lake Survey is the tremendous development of Lake commerce. This has been accompanied by an increase of drafts, — with 24½ feet or more to be available in the new "Soo" lock five years from now. The present importance of the Lake vessels requires closer surveys and developments to greater depths, and submarine searches by modern sweeping methods instead of the lead-line work of our ancestors. And the hydraulic questions having to do with the preserving of the Lake levels have become correspondingly important. The Lake Survey issues navigators' charts of the Lakes, 119 different ones in all. The artistic excellence of these charts is largely due to Assistant Engineer Edward Molitor.

The information service of the Survey is an important branch. We issue a yearly bulletin full of everything pertaining to the Lakes that might be of use or interest to navigators. We issue monthly magazine supplements, and issue to the press all over the Lakes special notices of new discoveries of shoals, wrecks, derelicts, new harbor depths, new channels, dangers and aids. For survey work we have five steamers and employ, when running full tilt, from 150 to 200 men.*

The geodetic work of the old Lake Survey is a classic and that of the new Lake Survey is a second volume, but to my mind the hydraulic work of late years, having in view the betterment of draft conditions by artificial control of the efflux, has a fuller interest.

It has been estimated that a change of a foot of draft in one of the large Lake carriers will make a load change of ten per cent. of her 19-ft. draft cargo-carrying capacity. That is, a vessel carrying 10 000 tons of ore on 19-ft. draft will carry 11 000 tons on 20-ft. draft, and 9 000 on 18-ft. draft, while the operating expenses will change very little between 18-ft. and 20-ft. drafts. Were all the vessels of the Lakes loaded down to 20 ft. instead of 19, the cargo, which now costs 56 millions to move, would be moved with a saving of four or five million dollars a year.

It is because every inch on the big carriers means fifty to eighty tons of cargo that owners load to the limit. In the "Soo" locks the government had to build breast walls to keep vessels off the miter sills and had to measure up their draft to prevent grounding and delay in the locks. It is for this same reason that vessel interests look with resentful eyes on the proposition to divert ten to fourteen thousand cubic feet down the Mississippi Valley through the Chicago Drainage Canal. This must appear to them a last insult. But this loss of eight or nine inches of draft, even though it cost a million or two dollars a year in increased freight charges, is trifling compared to the loss coming from the régime of low Lake stages. Whatever the cause of low water may be, it is a fact. In Lakes Michigan-Huron and reaching up St. Marys River to the lower entrance of the "Soo" locks, in the St. Clair and Detroit rivers and in Lake Erie it exists. Lake Superior is all right, and Lake Ontario may get

* For the benefit of a member of this Society, who said to me one day that we government men up in the Jones Building had a *close corporation*, I will say that Colonel Davis' office covers the third floor of the Jones Building. The Lake Survey has 8 rooms in the Campau Building and 8 rooms in the Old Federal Building, all on Larned and Griswold streets. I shall be glad to exhibit our work there at any time.

even uncomfortably high. I will speak later of the reasons why these latter lakes are well up.

Colonel Davis, in his reports on the 20-ft. channel, has for several years past reiterated — like the *Carthage must be destroyed* of the Roman Senator — this statement: "The improved channels were made available in 1897, but as the water levels have been *almost continuously below the mean stage*, the actual navigable depth has been *1 to 3 feet less* than 20 feet."

Remembering that a change of one foot draft on the big carriers means ten per cent. of load, the three feet lost mean over 27 per cent. of the cargo-carrying capacity destroyed; so that freight which should cost $1 a ton on 20-ft. draft, costs on 17-ft. drafts nearly $1.37; and as the consumer generally pays the freight, you and I pay more for bread and coal and lumber and steel and every product into which these enter, on account of low water.

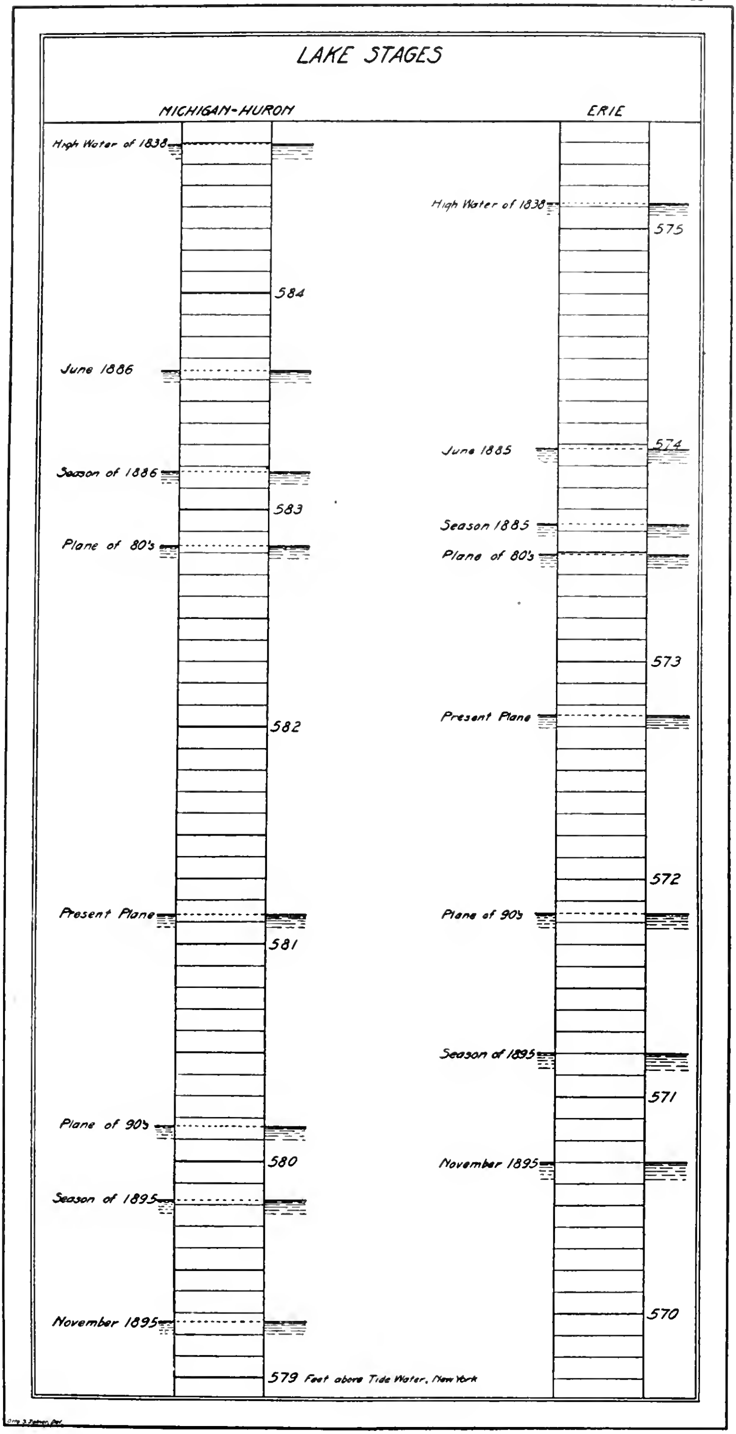
Not all the vessels of the lakes could load to 20-ft., — some of them are light draft, — but any figures that deal with ten or twenty years in the future may assume that the bulk, the big percentage of the freight, will be transported in vessels capable of deep-draft loading, — and subsequent figures will rest on this assumption.

Taking up Lake Michigan-Huron first, and remembering that the level of water in the lake affects the St. Marys River to "Soo" locks, and the St. Clair River, the mean elevation during the seasons of navigation for the 5 years, 1883–1887 (I shall speak of this as the *plane of the '80s*), was 582.8. It was considerably higher than this part of the time; 9½ in. higher during June, 1886, and 4 in. higher as a mean for the season of navigation of 1886. Plate 1 illustrates these levels.

Since this good Lake level existed as a *state* of *nature* for five years, and only twenty odd years ago, a *return* of the Lake to this level could not cause shore encroachments that might be logically resented or resisted; and as engineering works of importance have been constructed with a full knowledge that a series of wet years may bring the Lake back to this prior level, no damage should result. What is known as the *high water of 1838* was 23 in. above the *plane of the '80s*. During the past season the mean stage of the highest month, July, was 15 in. below this *plane of the '80s*.

Now I do not wish to commit myself to any particular Lake level as the right level — I am discussing the principle rather than definite limits — and this *plane of the '80s* is a convenient and defensible illustration.

SHENEHON
ON GREAT LAKES



From 1895 to 1899 was a five-year period of low water; I shall call the mean level during the seasons of navigation of these years the *plane of the '90s.*

This *plane of the '90s* is for Lake Michigan-Huron 2.6 ft., or 31 inches below the *plane of the '80s;* and in the season of 1895 the water was 3 ft. below the *plane of the* '80s. In November, 1895, it was 4.4 ft., or 53 in., below the level of June, 1886. That is, between *planes of the '80s* and *the '90s* there is 2.6 ft.; between extreme years, 3 ft.; between extreme months, 4.4 ft.

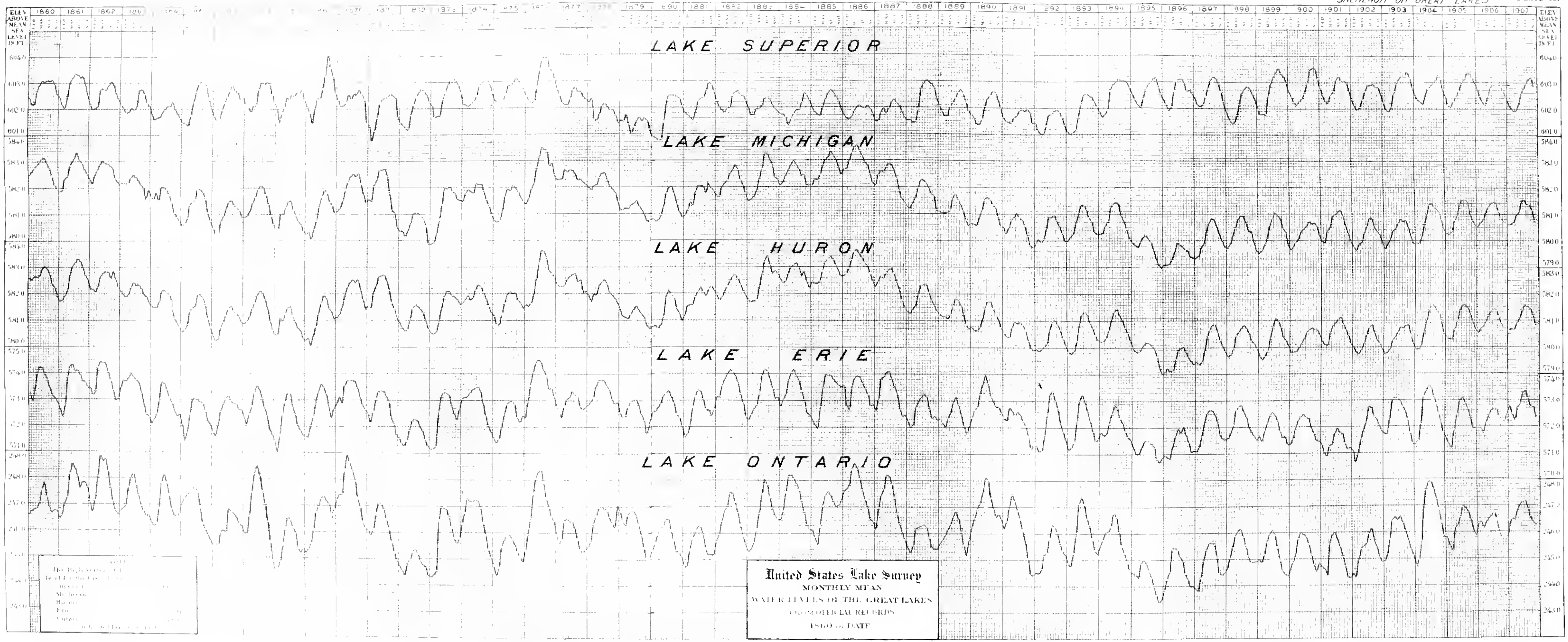
For 4 years now the level during the season of navigation has been much the same as during 1907; I shall call this the *present plane.* It is 1.7 ft. or 20½ in. below the *plane of the '80s,* with a loss of 14 per cent. in the carrying capacity of the heavy freighters, or 1 400 tons loss for each trip of a big carrier.

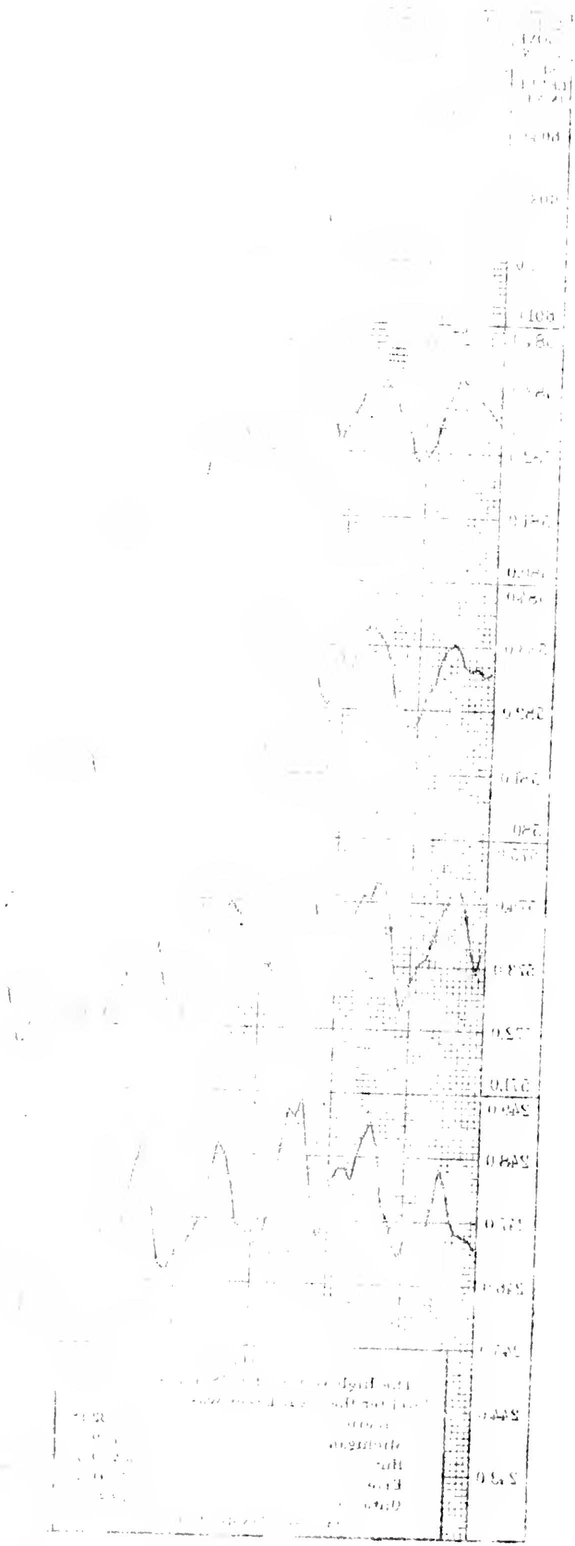
For Lake Erie the *plane of the '80s* is 573.5, and that of the *'90s* is 1.6 ft., or 19 in. lower; and during the season of 1895 the lake was 2.3 ft., or 28 in., below the *plane of the '80s;* and the change between single months is over 4 ft., as on Michigan-Huron. The *present plane* is only 9 in. below the *plane of the '80s.* This good stage of Lake Erie is likely to retard regulation, because it is not uncomfortably low; but the recurrence of the low water of 1895 is very certain, with a loss of carrying capacity of over 20 per cent. as compared with the *plane of the '80s.*

Please do not think I speak as a discoverer of the regulation of Lake levels. Roosevelt, you know, is charged with having discovered the Ten Commandments, but Moses had a whack at them some centuries before. Regulation is not quite so aged or quite so urgent as *some,* at least, of the Ten Commandments, but it is very far from new. The need of it was recognized fully in the early '90s, and the low water of 1895 brought the discussion to an acute stage. In 1898, the late Mr. George Y. Wisner, past president of this Society, as a member of the Deep Waterways Commission, urged the building of controlling works in Niagara River. In this project Lake Michigan-Huron was to receive its benefit by back-water effect only. It was estimated, as I remember it, that a rise of three feet in Lake Erie would raise Lake Michigan-Huron one foot.

At the present time another of our past presidents, Dean Haskell, of Cornell, as a member of the International Waterways Commission, is working anew on the problem of controlling works in the Niagara River.

The Lake Survey's part in these investigations, so far, is to


LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
LAKE ERIE
LAKE ONTARIO
United States Lake Survey
MONTHLY MEAN
WATER LEVELS OF THE GREAT LAKES
FROM OFFICIAL RECORDS
1860 to DATE



gather the physical data, water levels, river flow, evaporation, and make studies of rainfall and the like.

Though this question was acute, as I have said, during the low water of 1895, it has been growing vastly more important since, because the traffic is nearly *four* times as great now as in 1895.

What are the *causes* of this *low water régime?* Take Lake Erie, for instance: In order to get a navigable channel down the Niagara River to Tonawanda, dredges and drills have gone in and breached the natural dam; the Erie Canal and the Welland Canal take some water for navigation and some for power purposes. The power companies at Niagara Falls are suspected of having something to do with draining Lake Erie, and the Lake Survey has their case under consideration at the present time, but with no decision announced. Whatever water goes down the Mississippi Valley through the Chicago Drainage Canal is at the expense of Lake Erie. It is possible that deforestation of the shores and the plowing of the land have lowered the run-off by increasing evaporation, and are contributory causes.

Variations in rainfall and evaporation account for periodic low and high water. Each season the lakes rise with the early summer rainfall and run-off, and fall as the days grow drier. The seasonal curves are shown in Plate 2. This movement would be much reduced by controlling works.

If it be done *brutally*, it is exceeding easy to raise the level of one of the Great Lakes. Lake Superior, the biggest of all, was raised 6 in. by bridge piers and a wing dam at the head of the rapids in St. Marys River. The cross-sectional area of the outflow at the crest of the weir was reduced, and Lake Superior had to rise to get its normal outflow back again.

Lake Ontario has been raised 5 in. by plugging up, in 1903, a small part of the outflow at the Galop Rapids.

I say this method of getting better navigable depths is *brutal* because it increased the seasonal movement, and reduced the power to regulate against *high water*. It lacks finesse and foresight. Lake Superior has, since the building of her power canals, avoided any possibility of destructive high water, but Lake Ontario may experience the discomforts, if not the dangers, of high water. December, 1907, shows for Ontario the highest water for that month since 1876.

The *danger* of a Lake that in masquerading as Mr. Hyde cannot go back to Dr. Jekyll, in its destructive possibilities does not need to be dwelt upon. We want in the Lakes a condition of comfortable fullness, not *intoxication* nor the *orgies* that may

accompany a debauch. It is because of this danger of overfullness that the first move in Lake regulation needs to be for bigger outflow capacity than nature provided. You cannot regulate against high water otherwise. Back in the early '90s our president, Mr. Wheeler, gave out this principle, and I believe it to be fundamentally sound. There are some corollaries to this proposition, regarding independent outlets, that Mr. Wheeler may wish to speak about.

How are the lakes to be regulated? What form of controlling works? That is too large a subject to enter upon at this time of night.

Nature has a method of regulation that is excellent, so far as it goes. In the cold months, — January, February, March, — ice in the St. Lawrence River checks the outflow, and the average depth of water impounded by this winter regulative force is 7 in. on the surface of Lake Ontario. In the St. Clair River ice jams occur, and the outflow is reduced at times from a normal of 200 000 cubic feet to 74 000. Mr. L. C. Sabin, a member of this Society, computed the impounding value of ice in St. Clair River in 1901 as over 6 in. on the surface of Lake Michigan-Huron.

When the spring comes these controlling works of ice go out, and not a vestige of the apparatus remains. The channel has returned to its full unimpeded capacity. If these ice jams were placed only when *needed*, and kept in place as *long* as they were needed to accomplish the desired results, the system would be perfect. In the end engineers must take their cue from nature in this, but not to the extent of using ice jams, — dams or caissons rather, to reduce critical areas, as flashboards reduce the outflow area of a milldam.

I feel sure the *reinstatement* and *upholding* of the Lake levels will come; that the caprice of nature will be superseded by human foresight. I believe it is a worthy engineering project. The water of the Lakes is too valuable to run off without yielding up the full good that is in it. It is needed for vessel tracks, for sanitation and for scenic grandeur and water powers, as at Niagara Falls. There are 5 000 000 horse-powers in the vicinity of the Cataract at Niagara.

I spoke before of the vitality of the Lakes coming from the water. Low water is disease. The Lakes were sick in the '90s. The present semi-strength is only a rally, not convalescence. The bleeding must be stopped before the patient will know again the fullness of health, and here is a chance for engineering medication.

The spectacle of the volume of commerce grown to tremendous proportions — it is more than a third of the national commerce — while the tracks have dropped down to *inefficient levels*, is not a pleasant one. The process of dredging the bottom to keep pace with falling surface levels is a tedious and costly *stern chase*.

It is a much better proposition to uplift the Lake levels and let the water at one stroke come pulsing back into every harbor and channel, restoring and retaining the fullness of the *'80s*. That will mean good roads on the right-of-way of the Great Lakes.

Now, in closing I want to say that the steamer track from Duluth to Buffalo is 985 miles long; and the length of this paper is about the same. I thank you for your patience; I can excuse myself only as Tom Reed did when accused of running a billion dollar *Congress*. He said: "This is a *billion dollar country*" — and my paper to-night is *on* a *985-mile subject*.

[NOTE. — Discussion on this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by May 15, 1908, for publication in a subsequent number of the JOURNAL.]

MECHANICAL ENGINEERING AS PRACTICED ON THE ATLANTIC AND PACIFIC COASTS.

By George W. Dickie, Member of the Technical Society of the Pacific Coast.

[Read at the Annual Meeting of the Society, January 24, 1908.]

After spending thirty-five years in the practice of engineering on the Pacific coast, I am now spending a year and a half superintending work of a similar character on the Atlantic coast, and I find myself among new conditions and new methods. In this paper I will endeavor to compare, from an engineering standpoint, conditions as I find them here with those that obtain on the Pacific coast.

The Atlantic states, which front on the long Eastern seaboard, have been five times as long under development as the Western states; their population is much more numerous within a similar area; the markets for the products of their industries, both domestic and foreign, are correspondingly more extended and varied; their transportation facilities much more highly developed and convenient. Their great population supplies them with workmen, makes necessary the enterprises which demand the product of their engineering establishments, and their facilities for transportation put them in close touch with their markets. While the volume of business is so great, it is so not so much because of new demands for new machines to obtain new results, but rather for the same machines to do the same thing in a new locality or to increase the output in the same locality. Consequently, we find mechanical engineering establishments devoted entirely to the production of one machine or class of machines, where every part has been standardized, special machines installed for the cheapest possible production of every part and special workmen trained to get the largest output possible from these special machines. This condition is possible only where there is a large market for a special type of machine.

On the Pacific coast the conditions which would make such a system possible have not hitherto prevailed. Its manufacturing cannot be applied to the production of special machines, for the conditions which demand such a manufactory do not exist. The machines made there are not manufactured, but built one by one. Because of the variety of output which an

engineering establishment must produce in order to live, special machines to produce any one part are out of the question and workmen good at only one operation cannot be profitably employed. The Pacific coast establishment is, therefore, an engineering shop and not a manufactory, and in it anything possible in mechanics can be designed and built with a very fair prospect of meeting all the requirements demanded of it, but all the engineering skill used in the design and construction of this one machine goes with it, although it is quite as great as that required in a manufactory for the production of a thousand such machines; consequently the Western engineer must be constantly exercising his skill, experience and ingenuity in the design of new machines to keep his shop going, while his Eastern brother, having perfected a design to meet the general requirements of "the trade," may set his brain to work on eliminating all sources of loss in the system he has established for producing his machine at the lowest possible cost.

The principal difference is then this, that whereas the engineer in the West devotes his time and skill to meet the requirements of each customer, the engineer of the East perfects one machine to meet the requirements of all his customers and spends his time and energies in producing it at a cost that will insure it a ready sale in the open market. This difference results in the manufacturing, mechanical engineer of the East being able not only to undersell his brother of the West in machines that the general market requires in manufacturable quantities, but in many cases to successfully enter the markets of Europe, where the unit price of labor is much less than that obtaining in his own establishment.

On the other hand, should a client approach an Eastern shop with the outline of some piece of mechanism to meet some new condition, the development of which requires thorough and general mechanical skill, and, after the plan is developed, individual skill on the part of the workmen in the shop, to produce it, he will find great difficulty in getting a shop to undertake to carry out his ideas, and should he find one willing to serve him he would probably be surprised at the excessive cost of the undertaking. On the Pacific coast this original class of work is continually being made and the engineer and his shop are by constant practice ever ready to take hold of and carry to successful completion anything possible in mechanics, and that at a cost not much if any greater than ordinary work of the same complexity.

The reason for this is to be found in the difference in shop organization brought about by the variance in the trade conditions between the one locality and the other. In the East a thoroughly organized and often very complex system, working harmoniously along lines that are the result of careful study and much experience, produces a machine as perfect as the system of which it is the embodiment, irrespective of the mechanical ability and general knowledge of the operators. The workmen acquire highly specialized skill carrying out instructions according to the system, the staff becomes highly expert in applying and perfecting it; the system itself is or may be made perfect in obtaining the result for which it is intended; applied to a new condition it loses its efficiency in a greater or less degree, according to the amount of the deviation from the beaten track. In the West, on the contrary, owing to the necessity of turning out a product as varied as the mechanical needs of a new and developing country, a shop cannot have any particular system, except that of a general organization which must be elastic enough to adapt itself readily to widely different kinds of product, where no foresight can possibly prepare for the work that must next be undertaken.

The planning may be and often is along original lines, without precedent or general experience to guide the designer, and when the design reaches the shop where it is to be made, its growth must be carefully watched, for often the thing in metal does not look like its image in ink; the working mechanic may often be able to save the reputation of the designer by timely advice, the result of his practical experience with metals and his skill in working them. Hence, not only must the designing staff be able to design any kind of a machine that a customer may require, but his workers must also be mechanics of great skill and general experience to bring safely into working form the design that has just been brought from the fertile brain of his chief.

In the one case a perfect system produces at the least possible cost a perfectly planned and experimentally adjusted design without any skill on the part of the workman other than that required to perform his part in the system. In the other case a machine to meet special conditions is designed as skillfully and as perfectly as the engineer's skill and experience enable him to design it; it is built by skilled mechanics under a system that enables the designer or the skilled workman to modify the design at any stage of the production should occasion require it.

There are two principal points of view from which to observe the results that follow from the workings of these two radically different methods of production. They may be viewed from the position of the capitalist and from the position of the working man or operative, both of whom are involved.

A shop with the system so much to be seen in the Atlantic states, looked at from the capitalist's position, is a profitable investment for his surplus or inheritance and tends to create an upper class or controlling power in mechanical engineering.

Looking at it from the operative's position we see the extinction of all individual effort on the part of the mechanic to improve the product of which his work forms a part; lack of interest in his work, due to the repetition of the same operation on the same parts of a machine that he never sees finished; no prospect of a better condition or increased pay. Above the workman we see an array of college graduates operating the system and assigning the work to the operatives; above these the controlling head, whose engineering skill contrived the system and the machinery through which it operates, the man who has the confidence of the capitalist and whose position is established as long as the supply of skill to operate the system is plentiful, and this is secured by the yearly turnout of the technical and other colleges.

The shop organization on the Pacific coast from the capitalist's position is not so good; it shows no prospect of a large return to the investor, owing to the varied character of the product, each item of which involves new problems which, when solved, have no application to those succeeding them. The controlling head of the work has not the same security in his place as his Eastern prototype, for every day brings a fresh problem, requiring new applications of mechanical engineering skill; his power to work out these new problems is his worth, in virtue of which he retains his position and its emoluments. The problem he solved yesterday is not in itself a solution of the problem of the future; he cannot sustain himself on the success of the past. When the continual strain has told on his store of brain energy and he begins to blunder, he can no longer hold his post and is replaced by a younger and fresher man. He has not an automatic system to fall back on; he himself is the system.

From the working mechanic's standpoint the Western methods of shop organization present a brighter prospect. The better paid positions must be filled by men who know the things they order made and who have learned in the school of experi-

ence. Those whom they work under must necessarily have traveled by the same way in which the mechanics now are. To his ambition the view is promising; his brains and mechanical skill are assets of great possible value; he feels that by perseverance he may better his condition and obtain the better fortune to which he aspires. It is, then, from the viewpoint of the man who is willing to think, and work, to the progressive man, that the Western method appeals to us.

Let us examine these matters from the neutral position of those who are neither capitalists nor operatives, but who are interested not only in the progress of mechanical engineering, but also in the general prosperity of all their fellowmen. Such a view must take cognizance of both the ethic and economic effects of any system of production. It is from this point of view that I intend to look at the system which obtains in many large engineering establishments on the Eastern coast. The economic effect of the system from the standpoint of cheap construction is undoubtedly good, for it reduces the cost of the machine to the lowest possible point obtainable with the current rates for material and labor and thus enables the producer to reach markets that would otherwise be closed to him; it enables him to secure capital to extend his operations, because he can figure on the actual cost of production and the profits that can be secured. It is his system which enables him to eliminate the uncertainties of skilled labor and the difficulty of knowing how it will act.

Much of the work that under the simple organization of the West is done by the work's manager is done by a skilled force of computers, whom the system supplies with a great deal of more or less exact data which enable them to figure exactly what each man may be expected to do.

In his very interesting and elaborate Presidential Address on The Art of Cutting Metals, read before the American Society of Mechanical Engineers, Mr. F. W. Taylor gives a very complete history of the system that he has largely been the means of introducing, whereby the possible amount of work of any tool on any known character of material is computed on a special slide rule by a man trained and experienced in this work. This address, which amounts in its scope to a treatise, is undoubtedly of a high order of merit and is the most valuable contribution to engineering literature that has been made of late years; but in some particulars I wish to take exception to the methods advocated by its author. The result as obtained by the slide

rule is the work demanded of the operative. Mr. Taylor informs us that his greatest difficulties have been with skilled mechanics, men whose characters and abilities he had to respect, but who would not give up their habit of thinking for themselves; they refused to accept the decisions of the slide rule and had to give way to the man who was content to carry out instructions. As I thought of the result of this, and, like the men who had to be replaced, I could not help thinking, another way occurred to me, whereby the same result was obtained without dismissing the thinking workmen. While studying the system in operation at some large establishments in England, wherein the workmen as a body contract to do all the labor involved in the production of any given piece of work, I happened to be looking through one which had for a long time practiced this method. Observing an old machinist, with an interesting face, at a large lathe, I talked with him about this system and asked him whether it stimulated the men themselves to think of the cost and the quickest way of doing their work. In replying, he pointed to a young man working a smaller lathe nearby and said: "Now, there is a young man who came here from Glasgow some weeks ago; he is a good lathe hand, he knows everything that can be done with a lathe and does it well; we had to teach him only one thing and that was how *much* a lathe can do." This method arrives at the same result as Mr. Taylor's slide rule in obtaining the maximum output from each machine, and its moral effect is good. The moral effect of the system that has enabled the American manufacturing engineer to secure and hold markets, not only in his own country, but also in foreign countries where the workman does not secure anything like the wages paid to the American mechanic, cannot be called good.

I have tried to observe the condition of the workman under the slide rule system as compared with the condition of those who work in shops where the varied nature of the work does not admit of a system that may be rigorously carried out, but where the results obtained, both mechanical and economical, depend largely on the individual mechanical ability and moral character of the working man. The tendency of the rule system is to deaden all individual effort on the part of the working man; his interest in his work ends with the accomplishment of the task worked out for him on the rule; his outlook is not brightened much, even if he succeeds in beating it, as this feat means only a few cents more in a given time; he receives no stimulus from the completion of any finished piece of mechanism that he

has produced; he only sees gathering around him on the one side a pile of rough blanks all alike, which he, or rather the machine he operates, converts into another pile of finished parts all alike; that is all he sees and knows of the part he plays in a great industry. There is no nourishment in that work for the brain, and that man cannot grow; in fact, he loses the power to think and the desire to grow; he swiftly and surely becomes the automaton that fits so well into Mr. Taylor's slide rule system. Therefore, I say, the moral effect is not good — but how else is it possible to reach the market with a product that may be profitably sold at the price the market offers? The mechanical engineering establishments in the Eastern states have developed and perfected systems along these lines which are successful in making profits for the investors but have an immoral tendency towards destroying the independent, thinking mechanic.

The time is fast approaching, if it has not already come, when the Pacific coast engineering establishment must take special lines of work and perfect a system of manufacture that will at least secure for it the local market for its product; when that is secured, its growth will be commensurate with the growth of the population and commerce of the place. Is it possible to secure the economy of what I will call the slide rule system by some other method that will not displace the skilled mechanic? Is there, on the other hand, any system of management that will enable engineering establishments on the Pacific coast to continue doing business under the conditions that now obtain, where time wages are higher than in any other part of the world, and where to offset this the economic conditions of operating are low as compared with any system that determines the amount of production per unit of time? After careful study of conditions in the West, I am forced to the conclusion that unless a radical change is made in the method of doing work, mechanical engineering as a business will sink to the level of the small jobbing shop. These conditions, bad as they have been, are steadily growing worse. The workmen seem to forget that with modern means of transportation no section of this country, great as it is, can maintain conditions so radically different from those prevailing in other parts, as now attempted by them; the terrible condition of industrial engineering in this part of the country, where we were always proud of our high class workmen, is directly due to the forced and artificial value placed on labor by labor itself. It is hardly possible now to

go back to old conditions of hours and wages. If we are to continue to produce what we require of machinery, those managing the establishments that are to produce it will have to find out honestly what part of the possible selling price can be given to the workmen who convert the raw material into the salable machine, and contract with them or their representatives to do all the work for that amount; in that case the men can work long or short hours, as it may suit them; each man will be compelled by his fellows, who are his partners in the contract, to do his fair share of the work in order to obtain his pro rata of the reward. I have written so much on this method that to extend this proposition further would be only repeating what I have already said in great detail.

I do not think that the methods I find so extensively adopted in the East can be put in operation on the Pacific coast unless the present force of mechanics now usually on strike is entirely eliminated and a new race of operatives, willing to work under the slide-rule system, is introduced. Either the slide-rule system and a fresh supply of labor, or the contract system and the present force, must step in to save this struggling and now almost expiring industry.

A few months ago I had occasion to purchase a number of machines of a type that I had perfected on the Pacific coast to meet the special requirements there; the demand on the coast required about twenty of these machines each year and I used to make them in lots of twenty at a time, not so much for profit as for filling in and keeping the small tools in work. They were sold at $900 each and at that price they paid for material, labor and a pro rata of general expenses. I required sixteen of these same machines for the purpose I refer to and had the drawings from which they were made in San Francisco. The same machines I bought for $500 apiece at an establishment in Maine, where the facilities in tools and handling apparatus are not so good as in San Francisco. About sixty of these machines are now being made at the same establishment for the Pacific coast trade, and the business of making them there is stopped. The labor cost of this machine in San Francisco was $530, while the labor cost in the East is $210; adding the cost of transportation entirely to labor, the amount available for wages to operatives in San Francisco, assuming, of course, that the general expense and profit amounted to the same thing in these two cases, is $315. Since interstate commerce is free and unrestricted, the transportation charges represent the difference

available in the possible prices obtainable in the East and the West for such a machine as a continuous manufacturing proposition.

To so alter your conditions in the labor market that you may compete with the Eastern states is a present necessity if you would secure in mechanical engineering future prosperity. A change must come in the relations of employers and employed; a more intimate connection and co-relation must be established. To make the mechanic understand that there are practical and economically impassable limitations to the achievement of short hours and high wages; to make him realize that the price of any article being fixed, the amount available for labor is also fixed; to bring the employers to believe that the only way to prevent strikes and secure a lasting industrial peace is to have a thorough understanding between themselves and their employees as to the amount in the cost of any product that may be applied to compensate the workman for his toil; to teach employers the justice of frankly figuring out with their employees the cost of materials, expense of operating, profit required and amount available for labor; in short, to establish a just balance and to apply the Golden Rule to industry is the great problem to be solved by those interested in the development of engineering industries on the Pacific coast. Strikes and lockouts will never settle anything in industrial economics; their object is to destroy and in this their success is beyond dispute; as a means of settlement for any misunderstanding that may exist between employer and employed they should at once and forever be done away with, as entirely too crude for this age of enlightenment and progress.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by May 15, 1908, for publication in a subsequent number of the JOURNAL.]

Editors reprinting articles from this JOURNAL are requested to credit the author, the JOURNAL OF THE ASSOCIATION, and the Society before which such articles were read.

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FURNACE DESIGN IN RELATION TO FUEL ECONOMY.

BY E. G. BAILEY, JUNIOR MEMBER AMERICAN SOCIETY MECHANICAL ENGINEERS.

[Read before the Boston Society of Civil Engineers, December 18, 1907.]

IN designing a boiler plant, the ultimate object is to obtain the required steam at the desired pressure, temperature or quality at the least cost. The least cost does not include the coal bill alone, but, in addition to this, consideration must be given to cost of labor necessary for the operation of the plant, repairs, interest and depreciation on capital invested. A saving in the fuel bill alone in new plants or furnaces is not sufficient to prove conclusively that any particular design is the best. The labor necessary for economical operation, together with more rapid burning out or wear of certain parts, may more than offset the saving due to boiler efficiency alone.

The majority of the boiler plants in New England running 24 hr. a day consume in one year coal amounting in value to more than the original cost of the plant, so that it would pay to tear down a new steam plant before it had ever been operated if you could prove that by so doing you would make a saving of 5 per cent. There are many plants which have been in operation five or ten years that could be reconstructed to-day at a saving of 5 or 10 per cent. The question is, Why do they continue to operate that plant when the coal being used each year costs more than did the plant when it was originally built? In most cases it would be necessary to make only a few changes to greatly increase the efficiency. In order to determine what saving might be made in the design of furnaces, it is necessary to know

the magnitude of the various losses as they exist under the present conditions. It is useless to expect a saving of 20 or 30 per cent. from the use of certain auxiliary apparatus, as is often claimed, when the losses supposed to be reduced are far from being as great as the contemplated saving.

The heat balance of a boiler test as given usually includes the following distribution of the total available calorific value of the coal:

(1) Heat used for evaporation of water in boiler.

(2) Loss due to latent heat in moisture formed from the combustion of coal.

(3) Loss due to products of combustion, or sensible heat of gases produced exclusive of excess air.

(4) Loss due to air excess, or sensible heat of unused air leaving boiler.

(5) Loss due to unburned gases, consisting of carbon monoxide, hydrogen and hydrocarbons.

(6) Loss due to unburned coal or coke dropping into the ash pit or passing through flues or up the stack.

(7) Loss due to radiation from boiler setting and absorption by brick setting.

The relative magnitude of the above losses varies greatly, depending upon the kind of boiler, furnace, rate of combustion and method of firing. The results recently determined from 18 evaporation tests on a 200 h. p. return tubular boiler, hand fired, give some idea of the relative importance of the various losses as they occur in a stationary plant. The average of the above tests is as follows:

1. Heat used for evaporation	66.7
2. Loss due to latent heat	2.7
3. Loss due to products of combustion	8.5
4. Loss due to air excess	8.5
5. Loss due to unburned gases	0.8
6. Loss due to unburned coal	2.4
7. Loss due to radiation and absorption	10.4
Total heat	100.0

The important item is the heat used for evaporation or the boiler efficiency, which can be increased only by the reduction in one or more of the various losses as they now exist. The extent to which these losses may be reduced is dependent upon the kind of coal, method of firing or supply of coal and air, conditions under which combustion takes place, and extent and conditions of heat-absorbing surface.

Latent Heat or Moisture in Coal. This loss includes not only the evaporation of the moisture in the coal as usually determined, but that formed from the combustion of hydrogen as well. This loss is of small importance and varies but little for the different coals received in this market. It is a loss that is impossible to reduce, but it may be prevented in certain cases where coal is intentionally wet by the fireman. This is universally done on a locomotive, but it is necessary in this case to lay the excessive dust that would otherwise make the work very disagreeable.

Products of Combustion. The amount of gases produced from the combustion varies almost directly with the calorific value of the coal, so that the percentage of loss is practically constant except for variation in the flue temperature.

The temperature depends upon the rate of combustion, area of boiler heating surface and cleanliness of the same.

Air Excess. This loss is one of great importance, as it often exceeds 30 per cent. It not only carries away sensible heat, but reduces the furnace temperature, thereby reducing the efficiency. This loss may be affected to some extent by the character and quality of coal burned. A non-coking coal generally lies closer together and is less apt to allow holes to burn in the fire than a coking coal; also the formation of clinkers causes the air to pass through the fire in streams, thus causing high velocity in certain parts, and a hole is the result.

The fireman is largely responsible for the loss due to air excess because he does not keep the fire to the proper thickness for the draft, or he may fire the coal unevenly, allowing holes or thin spots to form. A series of tests was once made to determine the air excess with different thicknesses of fire, with uniform conditions with respect to draft, kind of coal, etc.

Thickness of Fire.	Air Excess.
4 inches	135 per cent.
6 ,,	92 ,,
8 ,,	75 ,,
10 ,,	62 ,,
12 ,,	50 ,,

These results were taken at the rear of a B. & W. boiler and include some air which leaked in through the setting and probably amounted to 20 or 30 per cent. The saving was 6.5 per cent. between the 12 and 4-in. fires.

The best method of determining the extent of this loss is by analyzing the gas leaving the boiler. This is usually done with the Orsat apparatus, but the automatic continuous recording

CO_2 machines now on the market make it much easier for the fireman to keep his fire in good condition, and the effectiveness of his work is permanently recorded. The tendency on the part of the fireman is to disregard such an apparatus, especially after it has gotten out of repair once or twice, but it is only through interest on his part that economical results can be obtained. A year's records of the past results will not increase the boiler efficiency. One per cent. of CO_2 means about 20 per cent. air excess, or 2 per cent. loss under average conditions of air excess and temperature.

The air excess as determined at the uptake from a boiler or at the bottom of the stack does not always show what the fireman is doing, as the air leaking through cracks in the brickwork, around clean-out doors and even the porosity of the brickwork, is oftentimes as great as or greater than the excess air passing through the furnace.

Results obtained from various plants show some interesting conditions, giving both extremes of air excess and the increase due to leakage through the boiler settings, flues and economizers.

From 250 h.p. Cahall boilers, hand-fired, burning New River coal, the CO_2 averaged above 16 per cent., corresponding to an air excess of about 15 per cent. The CO did not exceed 0.7 per cent., with a loss of about 1.4 per cent. of the heat in the coal. The same boilers burning No. 3 Buckwheat and Pennsylvania bituminous mixed in the ratio of 2 to 1 gave about 60 per cent. air excess.

A plant with 9 horizontal return tubular boilers were operating with a steam blower producing forced draft in the ash pit. With the blowers on, several gas analyses averaged 59 per cent. air excess and 1 per cent. CO, making a loss of about 4 per cent. due to each. When the blowers were shut off by the damper regulator the air excess went as high as 209 per cent., making a loss of 15 per cent., as compared with 8 per cent. when the blowers were in service. This high air excess resulted from the restricted area into the ash pit and the higher vacuum in the firebox, causing a large amount of air to pass in through the leaking brickwork of the boiler setting.

A plant with 20 horizontal return tubular boilers, hand-fired, gave 150 per cent. air excess leaving the boilers, and 180 per cent. leaving the economizer.

A number of tests made on a B. & W. boiler with Dutch oven furnace gave 35 per cent. air excess leaving the combustion chamber and 75 per cent. leaving the boiler setting.

A stoker-fired plant with eight 350 h.p. boilers gave 146 per cent. air excess over the fires, 230 per cent. entering economizers and 280 per cent. entering the chimney. The loss in this case amounted to about 30 per cent., due to air excess.

A hand-fired plant with several vertical fire tube boilers gave 90 per cent. air excess leaving the boilers and 250 per cent. leaving the economizer.

A chain grate stoker gave 240 per cent. air excess, the air leaking largely around the back end of the grate.

Unburned Gases. Usually the analysis of flue gases gives the carbon monoxide as the only unburned gas, but there are undoubtedly other gases that are not completely burned that are of higher calorific value than CO. They are seldom determined, owing to the difficulty of the determination. With the CO_2 about 10 per cent., the loss due to 1 per cent. of CO means about 5 per cent. of the calorific value of the coal. Under the same conditions, 1 per cent. of CH_4 means a loss of 16 per cent., and 1 per cent. of C_2H_4 causes a loss as great as 30 per cent. These and other hydrocarbons are very likely present in many furnaces where conditions are not favorable to complete combustion. In series of tests with an increasing per cent. of CO, the radiation and undetermined loss generally increases accordingly, indicating that there might be unburned gases escaping undetermined.

The combustion of these gases cannot be completed without sufficient oxygen thoroughly mixed at a high temperature. In order to accomplish this the furnace and boiler should be designed so that the heat will be generated in one and absorbed by the other. Both operations cannot take place at the same time and insure complete combustion.

The difficulty of obtaining the proper conditions increases with the per cent. of volatile matter in the coal burned. Smoke is an indication that these losses are occurring to a greater or less extent, but a smokeless stack does not necessarily indicate complete combustion.

An internally fired boiler is the most extreme case of violating the laws governing economical combustion with bituminous coals. It is practically impossible to prevent smoke under such circumstances, as some of the burning gases are extinguished by the lowering of temperature when the flame comes in contact with the water leg or enters the tubes.

Gas coal can be burned without smoke if the laws of combustion are properly considered and the furnace constructed so

that they can be carried out. The speaker had occasion to spend a month at a copper smelter in northern Michigan some years ago and there saw a case of complete smoke prevention. The larger smelters consist of a reverberatory furnace 30 ft. long and 17 ft. wide; the heat for smelting the ore comes from a furnace having a grate 8 ft. long and 11 ft. wide, which is separated from the smelter by a bridge wall only. Gas coal was being burned and contained about 35 per cent. of volatile matter. The method of firing was to put in 80 to 100 shovelfuls at hourly intervals. This is equivalent to firing 25 to 30 lb. of coal per square foot of grate per firing. There is a secondary air supply above and in the bridge wall, and the conditions for smoke prevention are evidently perfect, as the right amount of oxygen has plenty of time for thorough mixing in the smelter, in which a temperature of about 2400 degree fahr. is maintained.

Had a steam boiler taken all of the products of combustion from such a smelter, the boiler efficiency would probably not have been very high as a larger amount of heat would naturally be radiated from so large a firebrick combustion chamber. However it is evident that complete and smokeless combustion can be obtained by applying the Dutch-oven principle to the boiler furnace. Many hand-fired and stoker-fired furnaces are being used with a great deal of success so far as smoke prevention is concerned by making use of this feature in furnace construction. The more rapid the mixture of the oxygen and volatile gases, the shorter need be the firebrick combustion chamber, as the length of flame from various coals depends more upon the rapidity of mixture than it does upon the per cent. of volatile matter contained in the coal. The flame from anthracite coal and coke often extends 40 ft. from the bed of fuel.

The volatile matter is driven off from coal very rapidly after it is spread over an incandescent bed of coals. Some experiments were once made to determine the rate at which the gases were given off and the rate of generation of heat when coal was fired. The method of making these experiments was to put a certain quantity of coal on a wrought-iron grid and after it had been on the fire one minute it was withdrawn and the fire extinguished by placing the grid in an atmosphere of steam. This operation was repeated for different lengths of time with the same coal, and from analysis of the remaining coal or coke the loss in volatile and heat units was determined. A gas coal developed 30 per cent. of its total heat during the first five minutes and the volatile was reduced from 36 per cent. to 15 per

cent. A semi-bituminous coal developed 15 per cent. of its heat during the first five minutes and the volatile was reduced from 20 per cent. to 11 per cent. At the point of maximum liberation of volatile from the gas coal it was developing 1000 B.t.u. per minute. From these data the great variation in air required for complete combustion can be realized, and it is very doubtful whether there can be sufficient oxygen present at the critical time when coal is fired intermittently. The more uniformly the coal is supplied, the better the opportunity for complete combustion. One great advantage of the mechanical stoker is that it feeds the coal to the furnace continually, thereby holding the requirements for air in a constant ratio with the air supply. As none of the mechanical devices are perfect, they produce ideal conditions only to a certain extent.

Unburned Coal. In a stationary plant this loss is confined almost entirely to the coke or partly burned coal passing into the ash pit or drawn out the fire door with the ashes and clinkers. It varies with the opening in the grate, also with the per cent. of ash in the coal. The higher ash coals require more slicing and more frequent cleaning, and as the loss of partially burned coal varies with the working of the fire, it would naturally be greater. Some kinds of mechanical stokers are very wasteful in this respect unless careful attention is given to the part of the grate where the ashes fall off or are dumped intermittently. This loss from a chain grate stoker amounted to 16 per cent. in one test. In a locomotive the partially burned coal drawn through the flues is a very great loss; in some cases it was found to exceed 20 per cent. of the heat value of the coal. At the Pennsylvania Railroad locomotive testing plant at St. Louis they determined this loss to be about 8 per cent. by collecting the sparks, but after the tests were completed they found so many sparks on the surrounding buildings and ground that an estimation was made, which practically doubled this loss.

Radiation. This item of the heat balance is very difficult to determine directly, and is mostly taken by difference; hence it includes any errors made in the other determinations, as well as heat absorbed by the brickwork in the case of boilers with the brick setting. The latter error is one of frequent occurrence, as most tests are made under conditions more favorable to a higher rate of combustion and higher furnace temperature than during the 40 hr. previous. A paper read before the American Society of Mechanical Engineers some years ago gave the results of a 72-hr. boiler test on a B. & W. boiler burning Pocohontas

coal. The test was started with the brickwork cold, and after 60 hr. of firing the temperature of the wall rose 500 degrees fahr. The evaporation was checked every 6 hr., and there was a decrease of about 10 per cent. in the radiation loss between the first and latter tests.

Rate of Combustion. With the same difference in draft below and above the bed of fuel the rate of combustion varies with volatile in the coal; character of coal, whether coking or not; and upon the amount and nature of ash. In a high volatile coal a large per cent. of its weight is driven off regardless of the flow of air through the bed of fuel. A coking coal gives less area of opening through the fuel bed. Ash that does not clinker apparently reduces the rate of combustion but little. However, if this ash fuses at a comparatively low temperature, the clinkers formed reduce the amount of air passing through the grate by reducing the effective grate area by an amount equal to the area covered by the clinker. The more plastic the clinker the greater is this reduction in the rate of combustion, which is sometimes 50 per cent. within 8 hr. after the fire has been cleaned.

A great many smaller plants have difficulty in burning sufficient coal to keep their mill running, even with good coal. This result is usually caused by insufficient draft, as the horse-power required is beyond the capacity of the stack, or else other smoke connections have been added with no attention being given to the flow of gases. One case where two smoke connections met at right angles to the opening into the stack, and the velocity of the gases through this opening was 40 ft. per second, resulted in a reduction of 0.75 in. in draft through this one opening.

Another plant developing 1200 h. p. had a stack 4 ft. square and 85 ft. high. This stack would probably take care of the gases from 500 boiler h. p. unassisted by blowers. The plant in question had a forced draft fan connected to the ash pit of four of the seven boilers. The remaining three boilers had a draft of only 0.04 in. over the fire, so in order to assist the draft on all boilers, another fan was connected by a 16-in. pipe into the bottom of the stack and a current of cold air was forced up the stack. This would seem to be an inefficient method of producing draft, as the increased volume of air passing through the stack, which already is too small for the gases from the furnaces, and the lowering of the temperature of the gases in the stack, would both tend to reduce the draft. The only effective result would be the velocity of air entering the stack from the blower.

Coal Handling. The cost to handle coal from the cars or vessel to the furnaces varies considerably. In large plants, with coal-handling machinery and mechanical stokers, it can be handled for 18 to 20 cents per ton from barges, and 25 cents per ton from railroad cars. Where the coal is unloaded, passed and fired by hand, it costs from 40 cents per ton to as high as $1.25 in fair-sized plants.

DISCUSSION — at Meeting held February 12, 1908.

Mr. George H. Barrus (*by letter*). — 1. I am sure that Mr. Bailey merits the thanks and appreciation of the members of the Society for placing before them the results of his observations on fuel economy. I take it that most of the data given are based on the personal experiences of the author, and in this respect the paper is to be highly commended, for what we want most in these meetings is the report of practical results rather than untried theory.

2. I regret to find that the paper is in some respects disappointing. The subject, if we look at the title submitted at the previous meeting is, "Furnace Design in Relation to Fuel Economy." This appears to be a misnomer, for there is comparatively little in the paper that is devoted to the relation which furnace design alone has to fuel economy. It is in reality an account of the losses going on in the operation of steam boilers, whether due to furnace or any other causes. There are six principal losses discussed, but to only one of these losses is any relation attributed to the design of the furnace. The loss which is stated to be of the greatest importance, that due to excess of air over the quantity chemically required for perfect combustion, which is taken up at considerable length, is not attributed to furnace design, for the author states that the fireman is largely responsible for it.

3. The only loss I find here to which the title of "Furnace Design" is strictly applied is that headed "Unburned Gases." It is stated that to accomplish the combustion of these gases the furnace and boiler should be designed so that the heat will be generated in one and absorbed by the other. From statements further on I judge that, to provide for this division of the furnace and boiler, the author considers it necessary to use the Dutch oven principle, in which the furnace is entirely separate and wholly surrounded by brickwork. It would be interesting to know whether he has any other grounds for this conclusion than those mentioned or intimated. Does he think that the

economy of the return tubular boiler, on which the table of boiler losses given is based, would have been improved if it had been fitted with a Dutch-oven furnace? It would seem as though the loss of only 0.8 of 1 per cent., due to unburned gases which the table gives, represents the extent of the improvement possible, and that this is a very small inducement to change the ordinary type of furnace to the Dutch-oven system.

It would be interesting also to be informed in what manner he would apply the Dutch oven to the return tubular boiler mentioned, so as to make the saving noted, without increasing the loss due to the *radiation and absorption* of Item 7 to such an extent as to more than offset all gain which would result. My own opinion is that, if we liken the unburned gases to a disease and the Dutch-oven to a remedy, the remedy is worse than the disease.

4. The views of the author that the furnace should be separated from the boiler, are made even more pronounced by the statement that an internally fired boiler is the most extreme case of violating the laws governing economical combustion with bituminous coals. I hardly think this statement will be accepted unopposed by those who are most familiar with boiler engineering; and I would like to know whether the opinion here expressed is the result of actual tests of the author, or is it based on theory? I am sure the statement cannot refer to all types of internally fired boilers, for I have made tests on boilers of this kind and obtained fully as high efficiency as I have with an external furnace.

5. I would be glad if more data were given regarding the eighteen evaporative tests on the 200 h.p. return tubular boiler, such as duration, kind of coal, general conditions and objects, character of fire, capacity and flue temperature; also whether they represent average working conditions or test conditions. They can hardly represent the former, for the great majority of steam plants have more than a single 200 h.p. boiler, and the results obtained on a single boiler are hardly representative of those obtained on a plant as a whole. It seems to me also that they are not representative of the latter, for an efficiency of 66.7 per cent., which is here given, represents a low degree of economy for an ordinary evaporative test on a return tubular boiler. In a representative boiler of this kind, using coal that is not too high in volatile matter, there is no difficulty on such a test in obtaining 75 per cent. efficiency.

6. Nothing would be more interesting than to have the

author's ideas as to how, and to what extent, the various losses to which he refers can best be overcome and the efficiency improved. Referring to the second item of the table, would he have the fireman refrain from wetting the coal, and does he think that coal cannot be too dry for best economy? In Item 3, how would he reduce the loss due to the waste heat of the gases? Would he use a feed water heater in the flue? Would he preheat the air entering the ash pit by means of the waste heat of the flue? Would he endeavor to make the heating surface of the boiler more efficient? How would he change the design of the furnace, or that of the grate; or what would he do in regard to the relative dimensions of grate surface and heating surface? In the case of Item 4, what influence would he bring to bear upon the fireman to make him use air economically so as to prevent excess? Would he have the fireman carry the thickest fires possible in order to reduce this excess to a minimum, which might be inferred from one statement in the paper; or, if not, what thickness of fire would he recommend in order to get the proper proportions of air and combustible gas? Would he vary the air space in the grates for this purpose? Would he cut off altogether the air supply above the burning coal? Would he apply an automatic stoker to the furnace so as to secure the complete combustion that he intimates such a device gives, and overcome the loss noted in Item 5, or would he design some untried furnace to secure these results? Has he any method for reducing the loss in Item 6, due to unburned coal? What would he recommend for overcoming radiation losses from brick setting and otherwise, noted in the last item? In short, to what extent can these various losses be reduced in any specific case, like that to which the table applies, and what practical means can be adopted to secure the desired ends?

THE CHAIRMAN (MR. F. W. DEAN). — That is the only written discussion presented on Mr. Bailey's paper. Before Mr. Bailey comments on Mr. Barrus' discussion, perhaps somebody else has something to say.

In regard to Mr. Bailey's fear that, with boilers of the vertical type, in consequence of the unburned gases striking the cold heating surface so quickly, the combustion will not be completed; you have in the case of the horizontal return tubular boiler the gases going up immediately against the cold bottom of the boiler, and in the case of many water tube boilers the gases going up between the tubes.

I might mention also that in Mr. Barrus' book on boiler

tests, the boiler that gives the highest evaporation is the Manning boiler with crown sheet less than 5 ft. above the grate. That would indicate that it is just as possible to have as good combustion in a fire box surrounded by water spaces as it is in any fire box.

In regard to smoke prevention, I think the most smokeless chimney that I have ever seen was one at the Lower Pacific Mills in Lawrence, when they had Galloway boilers, with furnaces that were, I think, 30 in. in diameter. Little or no smoke could be seen from the chimney, although the boilers were pushed much.

Mr. W. G. Starkweather. — What kind of coal were they burning?

The Chairman. — Such bituminous coal as we usually get here, probably Georges Creek Cumberland. In a furnace of that kind, if you let air through the door, you are pretty sure it will mix up with the gases. It can't do otherwise, in fact. The mixture must be pretty intimate, and if the temperature isn't lowered below the point of ignition, then I think the smoke difficulty is solved. Certainly it was in that case.

Mr. Starkweather. — What you say about vertical boilers is borne out by our experience. We have used vertical boilers for a good many years. They have shown high efficiency, but we run across the difficulty of keeping scale off the tube-sheets. The tubes of our boilers are in rows radiating from a front hand-hole of large size, so that you can clean the crown sheet between them.

I think the boiler proposition is the large one to-day. It is not so much the utilization of the steam after you have it, as it is the getting of it as cheaply and smokelessly as possible. Steam engines have about reached the apparent limit of their possible efficiency. Of the various boilers on the market — and there are many types — certainly the internally fired boiler, such as the marine, gives fairly good satisfaction and develops high efficiency. In the marine service, however, they usually burn a very high class coal, a short flaming coal so that combustion can be almost completed before the gases get back into the combustion chamber and strike the tubes.

I was very much interested in the percentages of losses, as stated in the paper, especially the amount due to air excess, to radiation and absorption, and to air leakage. I believe we do not usually realize the amount of loss that can come from these causes. The question of air leakage is a vital one. The amount that can get in through loose mortar and around clean-out doors

pipes and flues, is something remarkable, and is a constant loss. Ordinarily you can close up those leaks with fire-clay and asbestos, thereby increasing the economy considerably.

High temperature in the uptake is a similar loss, but easily controlled. Many times a large saving can be made by decreasing the grate surface, burning perhaps a larger amount per square foot on a smaller total area, thus intensifying combustion and creating better conditions for the boiler.

The question of distance of the shell of the horizontal return tubular boiler above the grate is another important one. Personally, I think it should be as much as available space will permit. The additional radiation due to the brickwork is, of course, a loss, but that is not very serious if the brickwork is properly constructed. But, on the other hand, you gain a large combustion space, in which the hot gases and air can intimately mix and have time to combine.

I recall one instance where we supplied two 72 and 18 horizontal return tubular boilers in which the masons made the setting 22 in. thick and solid. It was much too hot to bear your hand on it. The radiation loss in that installation was very high.

A test was made in Milwaukee last summer by a Chicago consulting engineer which was interesting. The boiler was used for heating purposes and had a down-draft furnace for the utilization of western coal of about 13,000 B.t.u. It was 16 by 60 and 87 h.p., and we carried 14 lb. pressure. The boiler was run at its rating, and developed an evaporation of 9.27 lb. of water per pound of coal as fired. That gave us an efficiency of 78.76, which is higher than some experts, as Professor Kent, think possible.

In this connection you are doubtless aware that the coals used in the Middle West are very poor — low in fixed carbon, and high in volatile and ash; and that is one reason for the smoke nuisance in the Middle West. The atmosphere of eastern cities is much cleaner than that of Chicago, St. Louis and Cincinnati, for instance.

Usually that coal is sold at about half the price of steam coal in New England, and with proper handling will, of course, make steam very cheaply. For instance, in this case, the cost was 13.50 cents per thousand pounds. It was burned without serious smoke. Of course, the rate per square foot of grate was very low, 5.96 lb. If the Rhode Island coal can be utilized in any way, it would cause a remarkable saving in New England.

That coal can be delivered, I understand, for a dollar a ton at the mine.

The Chairman. — I think the only hope for that coal is in briquetting it.

Mr. Starkweather. — Perhaps it can be used in gas producers. Recent tests on it have shown carbon of from 65 to 80 per cent., volatile and moisture each 5 to 10 per cent., ash nearly 15 per cent., and less than 2 per cent. sulphur. No serious difficulty was found in generating a good gas in a producer, which apparently could be very effectively used in the gas engine as built to-day. This would materially reduce the cost of power for New England manufacturers, and there is a large quantity of it close at hand.

Mr. E. P. Sparrow. — My observation of the work of the particular boilers to which you refer, Mr. Chairman, tends to confirm the opinion that as a rule large units give the most satisfactory results.

Mr. Bailey refers to the losses due to excess air. This is a matter of far more importance than generally supposed. Eliminating leaks into setting, flues, etc., is all that is necessary in many cases to transform an unsatisfactory into a fairly successful operating plant.

Generally speaking, there is an excess of air passing through the grate, and I am of the opinion that the percentage of CO_2 found in the escaping gases from the average furnace is from 6 to 8 per cent. only.

As a matter of fact, there is no way to determine how perfect combustion is in any furnace, except by an analysis of the escaping gases, and it is not likely that any improved design of furnace or method of burning coal will automatically control the air supply or eliminate the personal factor in firing.

It is possible for an observer to make an analysis for CO_2 only, once in five or ten minutes.

But to get at a fair average, and to plot a curve showing what is taking place in the furnace, requires that the percentage of CO_2 be determined at frequent intervals, for 10 or 24 hr., as the case may be.

An automatic CO_2 recorder will furnish the desired information regarding combustion, the value of individual firemen, as well as other interesting information, which is not to be satisfactorily secured in any other way.

Such an instrument requires very little attention daily, and will give results well within 1 per cent. of that obtained with

an Orsat apparatus under the same conditions, which is closer than the work of the best fireman.

To get the best results the instrument should be thoroughly understood and handled with the same care and intelligence usually accorded an Orsat apparatus; if it is looked upon and treated as an ordinary piece of boiler room equipment the results are quite likely to be unsatisfactory and misleading.

THE CHAIRMAN. — I think one thing ought to be done in boiler plants, and that is to make the owners realize the importance of teaching their firemen how to fire. There are some places where they have a CO_2 recorder and compel the firemen to watch it, and where that is done I have no doubt the firing is very much improved. Now to illustrate what good firing can do, I had a very instructive case some years ago. By improved firing the evaporation was raised from 8.34 lb. to 12.84 lb. of water from and at 212 degrees per pound of combustible.

MR. STARKWEATHER. — Mr. Chairman, what do you think of the bonus or premium system of firing for the man behind the gun in the boiler room?

THE CHAIRMAN. — In what way is it applied? I don't think I know just what you mean.

MR. STARKWEATHER. — I refer to the establishment of a certain evaporation per pound of coal as a basis, and for every pound the evaporation is increased over that the fireman is paid a certain extra amount. For instance, say that 9 lb. is fixed on as his rating, and that he is to receive as a bonus $1 a week for every pound or fraction that he beats 9 lb. That puts him beyond the CO_2 recorder. It is then a question of his ability to get the best out of the boiler, based on his daily work and study of the operating conditions.

THE CHAIRMAN. — I should think it would be a good thing, but I think the CO_2 recorder would be a good thing to aid him in doing that. In other words, the bonus would cause him to watch the CO_2 recorder and enable him to accomplish his object better.

MR. STARKWEATHER. — Usually a fireman, if of ordinary intelligence, can judge very closely of the conditions under which his boilers are running from the way in which the coal is fired, and oftentimes is much better informed on his particular plant than any one else. Unfortunately, these men are ordinarily without education and know very little of the reasons for the various changes that go on in the boiler or the real effect of changes in conditions; but they do know how much coal they

fire and whether "she steams easier or harder," as they say. And they find ways of cutting down the air supply, increasing the draft or checking it, etc., to save labor for themselves. They are not interested so much in the coal as in their own labor. I think the fireman is a much neglected quantity in the boiler problem.

Mr. B. R. T. Collins. — I tried the bonus system in Chicago about ten years ago when I was in charge of the Harrison Street Station of the Chicago Edison Company. We had a CO_2 recorder and hot water meters installed in connection with all of the boilers, and I thought I would see what would happen if I offered a bonus for the best work. So I offered $2 a week extra to the fireman who made the best evaporative record combined with the best record with the CO_2 recorder. The men worked harder for that extra $2 a week than they ever worked before. It was remarkable to notice the increased efficiency of the station. I kept this up for six or eight months, and found that the effect of this system on the economy of the plant amounted to an increase in efficiency of between 10 per cent. and 15 per cent. In connection with the CO_2 recorder we had a pipe header with cocks arranged so that flue gas samples could be taken from any one of twenty-four boilers, and at night we would leave the recorder connected to one of the boilers and lock up the pipe header case so that the firemen would not know from which boiler the gas was being taken. The firemen, after firing each boiler carefully in turn, soon found out which one the recorder was connected to, and then the man in charge of that boiler would fire carefully and the others would do as they pleased. So it didn't work out at night as well as in the daytime when we changed the recorder from boiler to boiler at short intervals.

I also tried dividing the firemen into two classes. The firemen whose records in evaporation and CO_2 percentage were above the average were rated as first-class firemen. The men who were below the average were rated as second-class firemen. The pay of a first-class man was $2 per day and of a second-class man $1.89. A list of the two classes was posted every week, with the understanding that the man at the top of the first class would be the first to be promoted to a better job, while the man at the bottom of the second class would be the first to be discharged. This worked all right for a month or so. But one night when the peak of the load was on and we were carrying about 18 000 h.p., they all threw down their shovels and went out. I asked what the matter was and they said, "We don't

like this first- and second-class fireman business. We think we are all first-class firemen." I said, "You go back to work and I'll think it over." I thought it over for a week and abolished that system.

I want to ask the chairman a question as to his experience in the prevention of smoke with the ordinary B. & W. boiler setting. My experience has been that it is very hard to get smokeless combustion with such a setting. Have you had any experience with any special furnace arrangement for preventing smoke with the B. & W. type of boiler?

The Chairman. — No, I never had. My experience has been with the ordinary arrangement of furnace that is usually put up.

Mr. Collins. — There is generally a considerable amount of smoke with that setting when used with soft coal.

Mr. Bailey. — I have seen a B. & W. boiler set with a Dutch oven furnace that, with careful firing, was practically smokeless. I understand that at the Chicago-Edison plant they have an arrangement similar to what was put on the H—— boilers at St. Louis during the government test, and they claim absolute smokelessness from this in the Chicago-Edison plant. It carries the flue gases clear to the back end of the tubes under a firebrick arch which is composed of tile on the bottom of those tubes and then passes the gases right back in the opposite direction.

Mr. Collins. — I tried this arrangement about ten years ago at the Harrison Street station of the Chicago-Edison Company, and it worked out nicely on the H—— boiler. It amounted to a firebrick arch 13 ft. long over the grate and combustion chamber back of the bridge wall. The gases did not touch the tubes at all until they had traveled 13 ft. under this brick arch. This was with the H—— boiler, but I understand that it is being adapted to the B. & W. boiler.

Mr. Bailey. — I have never had an experience with that particular setting, but with the Dutch oven, hand-fired, it can be run practically smokelessly, with about an 8-ft. combustion arch, over a 5-ft. grate and a 107 h.p. boiler.

I think Mr. Barrus' discussion was much more premeditated than my original paper. I admit the fault of not adhering to my subject for one thing. The subject was given by me and several weeks elapsed before I realized I had to talk, and the talk being off-hand, I naturally strayed some.

Mr. Barrus takes up the matter pretty much in detail, and,

as he says, the data, and in fact the whole paper, was based on personal observations. Some of them had not been given a great deal of consideration since the results were taken, and oftentimes there was no chance to follow up with one plant and see just what could be obtained in the way of increasing the efficiency or changing the conditions. With regard to a good deal of his discussion, especially where he asks for more complete data in regard to the boiler plant on which that heat balance is shown, I will look up further data and answer specific questions of that character more definitely than I can to-night.

The heat balance given was the result of eighteen tests made on one boiler out of several similar boilers. It was due to the difficulty in weighing water for such a large plant that the one boiler only was used for these tests, the object of which was the comparison of different kinds of coal. The coals used ranged from 12 800 B.t.u. up to 14 400 B.t.u. as I remember it. Some of the coal was very high in sulphur and very high in ash. The firing was done by the regular fireman. He had another boiler to attend to in addition to this one, and he paid absolutely no attention to the test. He didn't care whether the CO_2 was 5 or 15. He wasn't given one word of instruction throughout the eighteen tests. The idea was simply to see what could be done under actual working conditions with the various coals. I will give more specific data as to the air excess and flue temperatures when I have the figures available. But the one interesting point from this number of tests was that throughout that range of ash, a considerable range in the amount of clinker formed, and the range of calorific value, the boiler efficiency did not vary but about 2 per cent. between the 12 800 B.t.u. and the 14 400 B.t.u. A secondary object of these tests was to see how closely the chemical analysis and the B.t.u. compared with the actual boiler results. Some people are skeptical about laboratory results because they are not practical. What they want, they claim, is coal that will evaporate the most water per dollar. That is true. That is what everybody wants for the steam coal. They consider chemical or laboratory results are all theoretical and far from reliable. But a review of the locomotive tests made by the Pennsylvania railroad at St. Louis, and also of those made by the United States Geological Survey at St. Louis, where they are conducted under as nearly the same conditions as possible, so far as the boiler is concerned, will almost knock the faith in boiler tests out of any one. The results are apparently up and down with no accountable reason.

In trying to derive useful information from the four hundred boiler tests, Professor Breckenridge has recently published "A Study of Four Hundred Steaming Tests." It is noted that many of the curves do not fall in any regular line. As many as five to forty different tests are averaged for one point on the curve. If each one of those tests was taken individually and plotted on coördinate paper, it would simply be one mass of spots. And it is only by averaging up all the variations that enter into each individual test that any plausible rules governing the efficiency, or the completeness of combustion as being affected by air excess, or the kind of coal, or the percentage of ash and the various classifications given, can be laid down; and it is really discouraging for any one who has been accustomed to depend a great deal on one single test.

As Mr. Dean just mentioned, in his tests at Lynn there was a variation of practically 100 per cent. between the first test and the last. So that if the fireman or the condition of the grate can affect the test by 100 per cent., it seems as if it would be a difficult matter to determine the relative value of two coals within less than 5 per cent., and 1 per cent. may mean thousands of dollars per year in the efficiency of the boiler. One person can prove conclusively that the internally fired boiler will give, say, 75 per cent. efficiency. In another case it may give 50 per cent. The Dutch oven may give 50 per cent. in one case and 75 in another. There are so many other conditions that enter in. It is very difficult really to tell what is the most economical coal from evaporative tests alone, or what is the most economical furnace or boiler setting. And it is only by a series of tests, where the average will eliminate the minor variations, that any reliable results can be obtained.

Now, as to the question of internally fired versus the Dutch-oven type. As I have just said, it is hard to prove conclusively in any particular case or set of cases that one furnace is superior to another. But in every series of boiler tests in which I have had occasion to plot out the results and try to learn something of the laws governing the efficiency, I find that the radiation of undetermined loss always increases as the percentage of CO, and generally with the rate of combustion. And in this test here the loss of 0.8 per cent. of unburned gases should read, "loss due to CO," because the heat due to the escape of carbon in the form of smoke and hydrocarbons present was not determined, as the Orsat apparatus was used. And every test, or series of tests, points to that one factor — that there are gases escaping un-

burned that are never determined, and the only way they show up in the heat balance is by measuring radiation or undetermined loss. And this loss does increase very decidedly as the CO increases with the ordinary flue gas analysis.

The Pennsylvania Railroad locomotive tests at St. Louis were made on eight different engines. Six of these boilers had a firebrick arch. Two of them had not. I can't give the exact figure, but the per cent. of loss due to CO alone was as high as 16 per cent. in some of those cases where there was no firebrick arch in the fire box. It seldom exceeded 3 or 4 per cent. to my recollection, in the furnaces where there was a firebrick arch. And the average of all the tests with the firebrick arch and of those without showed a decided difference which nobody can question. And there was evidently no reason for this difference in the CO loss, except the firebrick arch. In all cases, the rate of combustion varied from very low to extremely high, and the loss due to CO increases proportionately to the rate at which the boilers were forced.

Mr. Bement, of Chicago, and several of the engineers who have got to solve the smoke problem in the West, all point to the fact that the combustion cannot be completed in a short distance. A firebrick arch covering the combustion chamber and some method of mixing the gases must be used, or not only smoke, but unburned hydrocarbons, will escape. And as to the question of unburned gases, the practical fireman can tell you a great deal. When he gets the unburned gases afire in his smoke connections or in his stack, he will see the flames issuing from the stack or funnel, as I have seen them on a steamboat burning north England gas coal, containing over 30 per cent. volatile matter, in Scotch marine boilers. When the fireman put in a good fire, and by a spark or some means the unburned gases issuing from that stack together with the dense black smoke caught fire, immediately the flame sprang out of that 8-ft. funnel and shot into the air 10 to 20 ft. There wasn't a particle of smoke issuing from the top of that flame. The combustion was complete, but the temperature of the unburned gases was somewhere in the neighborhood of 1 500 degrees fahr. . . . So if you take into account all unburned hydrocarbons, you will still have the same boiler efficiency. The loss occurs just the same. Not later than yesterday I saw in a return tubular boiler where the combustible gases were going through the flues in such quantities and at such temperature that the opening of the uptake doors caused the gases to ignite and the smoke connection

was raised to a bright heat in a short time. I have seen that repeated time and time again. I have seen several pyrometers broken by being heated to the temperature resulting from the burning of those waste gases. Now, while there is no evaporative test going to show what this amounts to through a period of 10 hr. when the fireman is on his guard, yet if we did have not only CO_2 recorders, but CO and hydrocarbon recorders, we should find in the average day that this loss was a tremendous quantity in certain boiler installations.

The question of air excess in connection with these unburned gases is very interesting, and especially the infiltration of air through the brickwork. These two losses come inversely to each other, as a rule. With high air excess your unburned gases are low. As you reduce your air excess, you increase the possibility of unburned gases escaping. So that there is a happy medium in between, where you have the same loss due to each, and the sum of the two is the minimum. One disadvantage of the CO_2 recorders is the tendency on the part of the fireman to try to get too much CO_2. There is very little gain in economy after it reaches 12 per cent., because each per cent. of CO_2 then means not more than 6 to 10 per cent. air excess, while in the neighborhood of 5 or 6 per cent. of CO_2 it means about 50 per cent. of air excess for each per cent. of CO_2. So that when a man tries to keep his CO_2 extremely high, the loss due to unburned gases increases and oftentimes more than counteracts the saving which he has made by reducing the air excess. For instance, in a large power plant, before they put in CO_2 recorders, the CO_2 ran between 7 and 8 per cent. And when the fireman was watching the machine and doing his best, it ran up to 14 or 15. The CO and hydrocarbons were not determined, and had they been the loss due to them would probably have counteracted, or even more than counteracted, the difference in saving they would have made if they had only attempted to keep the CO_2 at about 10 or 11 per cent. A leakage of air through the brickwork is one of the most interesting things, I believe, that any man with an Orsat apparatus runs into. The clean-out doors need only be left open a quarter of an inch, and a little half-inch crack here or there to let as much air through the boiler setting as is going through the grate. The flue temperatures are often found to be below the temperature of the water in the boiler. There must be some cooling action or this could not occur, and the analysis of the flue gas generally shows where the trouble is. Speaking of the air spaces in the boiler setting reminded me of

a plant of return tubular boilers where, in order to prevent the cracking of the brickwork, some half-inch pipes were put in through the outer wall leading into the air space. By means of these holes it was very easy to measure the draft in this air space. And with the 0.6-in. draft over the fire we measured about 0.3 in. draft in the air space. There were several half-inch pipes supplying air into this air space, and still the vacuum maintained was half that of the furnace. The inner lining, which was solid showed a large amount of air was leaking through the porous brickwork and mortar.

Another case where we analyzed the gas in a 350 h.p. B. & W. boiler, we took one sample within 20 in. of the inside wall, where two boilers were set in battery, and another sample within 20 in. of the outside of the boiler wall, we found the air excess to be 180 and 205 per cent., respectively, in the two cases.

The question of smoke is one that everybody claims is not a serious loss. They figure 1 per cent. as covering the real loss of carbon particles. That is a figure that seems to be in every body's mind, and nobody seems to know who determined it, where the figure came from, or how authoritative it is. But even if this loss is only 1 per cent. the public sentiment is such that this problem must receive consideration. And I believe that in Boston there is less of an attempt to solve this problem on a real scientific basis than there is in many other places. In Germany and England it has been found that a fine is not sufficient to prevent this nuisance. So societies have been organized that have gotten the scientific, the practical and the financial men together in the hope of finding a remedy for this smoke problem and preventing it by scientific and practical methods. And from what I can learn, they are meeting with much more success than we are in many parts of the United States. I recently read a report of a committee of the city of Syracuse on smoke prevention, and I think it will pay any one to read that report simply for the literature and information collected on the subject, and for the scientific and practical way in which the subject has been handled. It seems that here in Boston there is no particular standard for smoke. There is a law that specifies that dense or dark gray smoke shall not issue from a stack longer than six minutes during an hour. And the question is, What is dense or dark gray smoke? No two people can agree on it, and there seems to be great difficulty in determining what density of smoke comes within the law and what does not. The man who owns the plant is very backward about paying any fancy

wages to his firemen. He claims he is paying as much as the next man and that his firemen are as good as any.

THE CHAIRMAN. — Excuse me for interrupting, but this Syracuse report is issued by the Chamber of Commerce, isn't it?

MR. BAILEY. — I think it is; yes.

THE CHAIRMAN. — I think, unless they are all gone, anybody can get one of these reports by writing to the Chamber of Commerce for it.

MR. BAILEY. — I am sure he can. I will just speak a few words further in regard to the heat balance. As Mr. Barrus has said, evaporative efficiency of such a boiler should be 75 per cent. In looking over the losses, the first is the latent heat, which is impossible to reduce. Had these heat balances been figured on combustible or dry coals as a basis, the efficiency would have been higher. But for several reasons I think results based on dry coal and combustibles are misleading, because what a man burns is actually wet coal — not exactly wet, but containing moisture. And all the results a practical man cares for are results based on coal at the price he pays for it. And it may be that Mr. Barrus is confusing this heat balance with one based on combustible.

The loss due to products of combustion is a function of temperature, and loss due to air excess is both temperature and the amount of air passing through the fire. The latter could probably be reduced to 3 per cent. under the best of conditions. That would save 5.5 per cent., which would throw the boiler efficiency up to 72.2 per cent. And unburned CO might increase it to 73 per cent. The only other place to recover loss in the heat balance as given would be in unburned coal, and it is seldom that this loss is lower than the figure here given, as it is unusual to find refuse that contains less than 20 to 25 per cent. of combustible in it. In most plants the principal thing that the fireman has to do is to keep steam. And in order to keep steam on a given boiler grate surface, he has got to keep the ash and clinker off his grates. It is much more important to do this and maintain steam pressure on a minimum number of boilers than it is to save a possible half of one per cent. due to loss of unburned carbon. A thing that frequently comes to my notice is that in cleaning fires the fireman will sometimes let his fire burn down to a very black grate — nothing but ashes and clinkers. The cold air passing through the bare grate probably carries away ten times as much heat as would have been lost if the fireman had pulled out a small amount of unburned carbon. Unburned

carbon is something he can see. Air excess is something nobody sees.

Loss due to radiation and absorption. This on any type of boiler is impossible to reduce, unless it contains, as I previously said I believed it did, some loss due to unburned gases. The amount that this loss should be is a considerably mooted question. Professor Kent seems to think it ought to be in the neighborhood of 4 or 5 per cent. Other tests show it as high as 12 or occasionally 15 per cent. When a person considers that this loss includes not only the loss, but all the errors in determining the average heat value of the coal fired and the average air excess, and when you consider the velocity of the air, changing from time to time to different parts of the flue, and the amount of unburned gases, especially of hydrocarbons, which are exceedingly high in calorific value, it is not at all surprising that this value should vary considerably.

On a set of locomotive road tests that I once assisted in, we found our heat balances checked up and left not more than 2 or 3 per cent. of loss due to radiation. This, of course, was where your rate of combustion was exceedingly high and your B.t.u. loss in radiation was figured on a very large basis. If that boiler had been run at the ordinary rate that is usual in stationary practice, the same number of heat units would probably have been radiated per hour, and it would have made considerable difference in the percentage of total heat being generated. The locomotive tests at St. Louis, unfortunately, did not go into the boiler part of it sufficiently far to show the heat balance. But in figuring out some of them I find that the radiation loss varies from a minus quantity to plus 20. And this is partially due to our inability to determine the amount of unburned gases as well as unburned carbon which was passing out of the stack. In each case they found it to be about 8 per cent., and then they found sufficient carbon lying around to give them ground for practically doubling it. On these other locomotive tests I referred to, they determined this loss of unburned carbon passing out of the stack by taking a sample of coal and determining from the weight of the coal the percentage of ash or the total amount of ash that was fired into the fire box. From the weight and analysis of refuse taken out of the ash pan, the total amount of ash falling into the pan was determined. Then by collecting a sample of the cinders and sparks passing out of the stack they determined the percentage of ash in that, and knowing the weight of ash passing through the tubes by difference, they were able to figure

the total weight of sparks passing out of the stack. In every case, the test running 72 miles, this loss amounted to 15 or 20 per cent., and over 2 000 lb. of sparks were thrown out of that stack for every test. I was very much interested, in view of these figures, in reading in the paper the other day about a cinder, spark and smoke observer riding on a Boston & Maine engine. He had a few ounces of cinders as a sample; and the newspaper correspondent said what a wonderful thing it was to collect them in a little tin can rather than to spread it out over the passengers. A tin canful of sparks in comparison with 2 000 lb. in 72 miles shows clearly how the newspaper correspondent comprehends the difficulties in complete combustion and general boiler work. I don't know that I have covered every point, but it is getting late and it is rather difficult to think of all the things mentioned by Mr. Barrus in this short time.

Mr. Bailey (*by letter*). — Further replying to paragraphs 3 and 4 of Mr. Barrus' discussion, I do not want to be misunderstood as stating that all bituminous or semi-bituminous coal should be burned in a Dutch-oven furnace, nor that no internally fired boilers are running with a fair percentage of efficiency. But for smokeless and complete combustion, the combustible gases must not be cooled below the ignition temperature before they are brought in contact with oxygen. In some boilers, internally fired or otherwise, the remedy of change in furnace design might be worse than the disease, depending upon the rate of combustion, method of firing, kind of coal, smoke restrictions, etc., but that there is more possibility of incomplete combustion in cases where heat is being absorbed at the same time it is being generated cannot be questioned. I have recently had occasion to analyze gases from an internally fired boiler, using not only the Orsat apparatus, but also the Hempel, and the hydrogen and hydrocarbons were determined as well as the gases usually included in the analysis.

A few analyses are given to show that an appreciable percentage of CO and CH_4 may be found in the presence of enough oxygen to have completely burned them had they not been cooled below the ignition temperature before the small percentage of oxygen came in contact with the small percentage of combustible gas. Take the case of sample 9, Test M, with 3.7 per cent. oxygen and 1.5 per cent. CO; the CO should have had 0.75 per cent. more of oxygen to have completely burned it. The oxygen present was five times as much as the CO required, but these two gases were diluted with about 95 per cent. of nitrogen,

carbon dioxide and water vapor. They were traveling at about 25 ft. per second through an average distance of about 4 ft. from the bed of fuel to the entrance to the tubes, thus giving about one sixth of a second for the CO and oxygen to find each other among 95 per cent. of inert gas.

The following gas analyses are by volume:

Test.	Sample.	CO_2.	O.	CO.	CH_4.	N.	Air Excess.
M	9	14.4	3.7	1.5	....	80.4	21%
M	10	13.3	2.1	6.2	0.9	77.5	11
M	Average all,	11.34	6.73	1.71	0.32	79.90	48
P	6	13.3	0.3	7.2	1.25	77.95	1.5
P	7	11.4	7.0	0.9	....	80.7	50.0
P	Average all,	11.88	5.80	1.97	0.40	79.95	38.0

Test.	Sample.	Air Excess if all Oxygen had been used.	Loss due to Air Excess.	Loss due to CO.	Loss due to CH_4.	Loss due to Unburned Gases.
M	9	16%	2.1%	4.7%	...%	4.7%
M	10	—17	1.0	19.4	8.4	27.8
M	Average all,	32	5.2	6.6	3.7	10.3
P	6	—43%	0.1%	21.8%	9.1%	30.9%
P	7	45	5.4	3.7	...	3.7
P	Average all,	23	4.1	7.3	4.4	11.7

Not only do the analyses show that free oxygen may occur with combustible gases, but from the two samples 9 and 10 in Test M, and 6 and 7 in Test P, we see that the gases coming through one set of tubes are entirely different from those coming through other tubes at the same time, as these two sets of samples represent such conditions. The average loss due to unburned CO and CH_4 is greater than the entire radiation loss from a Dutch-oven furnace and brick boiler setting. It would seem that in this case it would pay to apply some remedy. I believe that a more careful investigation of the composition of the flue gases would show a chance to make a great increase in the average yearly efficiency of many boiler plants. It may be possible to obtain a very satisfactory efficiency from any boiler when properly fired for a few hours during an evaporation test, but in order to economize in the annual fuel bill you must eliminate the possibility of a fireman wasting coal when you are not conducting evaporative tests or carefully supervising his work.

Referring to paragraph 5 I will give some additional data regarding the general condition of the tests referred to, more than has been given in the fore part of this discussion. The kind of coal was variable, the volatile ranged from 15 to 31 per cent.

The boiler was hand-fired, by the alternate method, and the bed of fuel was about 10 to 12 in. thick. The load was very uniform at about 30 per cent. above rated capacity. The flue temperature was about 490 degrees fahr., and the air excess was about 110 per cent.

How and to what extent the various losses of a steam boiler heat balance may be reduced and still have a net saving is a question that cannot be answered the same way in different cases. In many plants it pays to heat the feed water in economizers, while others have so much waste steam that the per cent. gain due to heating the feed water by the flue gases would not pay for the installation and maintenance of economizers.

No specific method of reducing the losses can be equally well applied to all plants, as the conditions vary so greatly with reference to kind of coal, uniformity of load, size of plant, character of labor available, etc.

Complete combustion of fuel with least possible amount of excess air is of primary importance in every case. It is of equal importance to absorb a large percentage of the heat developed by means of clean boiler heating surface, rightly proportioned to the amount of coal burned.

The most economical thickness of fire depends upon the kind of coal and intensity of draft, as well as the method of firing. Sometimes you will get the best results with a 4-in. fire, while with another coal and the same draft a 10-in. fire may be required.

As to mechanical stokers or other boiler room appliances, it is of common occurrence to see one plant discarding that for which another is placing repeat orders; and the reason why one plant found the apparatus a paying investment and the other considered it as a loss is very often traceable to the personnel of the boiler room labor and management rather than to the apparatus itself.

Mr. Francis H. Boyer (*by letter*). — We are under obligations to Mr. Bailey for his carefully prepared paper. The demands made in all our large cities and towns that boilers shall be so constructed and operated as to prevent smoke in any large amount being discharged into the atmosphere is surely a great stride for perfected combustion of coal and, therefore, economy in cost of operation.

Much of the fault of smoky fires from boiler setting is caused by the boiler being set too close to the fire. The distillation of gases from coal begins at quite a low temperature, from 150 to

200 degrees, depending on its quality. At this point atmosphere must be introduced into the coal gas; and when a temperature of approximately 500 degrees is reached by the combination of gas and atmosphere, the combustion becomes a fact, and the intense heat from 1 000 to 2 500 degrees takes place. In contact with the shell of the boiler, which at 100 lb. steam pressure per sq. in. is 312 degrees fahr., the combination of coal gas and atmosphere is rapidly cooled and will necessarily have to undergo a heating process before the combustion is complete. If this does not take place, then the combination of gases escapes to the atmosphere a black mass of smoke, or adheres to the shell of the boiler or tubes or brickwork as unburned soot or carbon to again be consumed when the heat reaches the proper temperature for combustion.

It follows that in setting boilers it is a good rule that works well, to set the boilers a long distance from the fires. This can be best seen in manufacturing plants where large fires are in use for heating metals or closed fire boxes. For instance, in a large forge shop, we often find boilers consisting of a shell, 72 in. in diameter and 20 ft. long, filled with tubes and set on end, at a distance from 30 to 75 ft. from the fire, or, if horizontal, encased in brick and placed up in the roof or walls of the building 30 to 75 ft. distant. The combustion of gases from these fires is complete before it reaches the boiler, and only the heated gases convey the heat to the surface of our steam boiler.

The placing of boilers away from the fires a distance such as to positively permit the combustion of the gases and allow only the heated refuse to deliver the heat, is in the line both of perfect combustion and of economy in fuel. This is well illustrated in the Dutch-oven construction. Many devices have been introduced to produce this result; one, by Dr. A. E. Kent, of Cornell University, consists of placing columns or structures of fire tile in the fire, which at all times is of a temperature sufficient to heat the entering gas enough to produce combustion.

In Mr. Bailey's paper he has shown up the proper condition when he describes the ore smelter in Michigan. After giving the size, he says that he has often seen from 80 to 100 shovels of coal thrown in the furnace at one firing, the furnace and smelting pan being only separated by a bridge wall in which a temperature of 2 400 degrees, approximately, was maintained.

Mr. Bailey does not tell us whether the air, forced through the fire or over the bridge wall without passing through the fire, was heated before entering or not. It is safe to say that it was

so heated. This is the ideal condition for complete combustion as no surface presents itself for cooling the gases before the complete combustion is made.

A good story of Mr. ——, who installed the electric plant at Berlin in or about 1895 or '96 for the New York, New Haven & Hartford Railroad for the service of their experimental electric road between Berlin and Hartford, is told as follows:

The foundation for the boiler was complete (horizontal tubular pattern). The boilers were in place and blocked up, the walls were about to the lugs, with the usual 30-in. clearance between the grate and the shell of the boilers. After inspection, Mr. —— ordered the boilers raised 4 ft. from the grate to the shell, and gave orders to notify him when the brickwork was up to the lugs. After the second inspection, he ordered the boilers raised another 4 ft., or a distance of 8 ft. from the grate to the shell, and the mason work was completed. It was the privilege of the writer to visit this steam plant at Berlin at the time of the American Society of Mechanical Engineers' meeting in Hartford in 1897, and the working of the boilers was satisfactory, with no smoke from the furnaces and to all appearances complete combustion.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by July 1, 1908, for publication in a subsequent number of the JOURNAL.]

ECONOMICAL LUBRICATION OF LARGE PLANTS.

By William M. Davis, Member Engineers' Society of Western Pennsylvania.

[Read before the Boston Society of Civil Engineers, December 18, 1907.]

In the lubrication of a large plant the first consideration is, of course, efficiency, then economy, although some engineers seem to think that it is impossible to attain the first and at the same time give any consideration to the latter.

To obtain efficient lubrication the most important thing is to know that the lubricants used are of good quality, either by choosing well-known or tested brands, or specifying what they shall be composed of and to what tests they shall conform. Next, see that suitable and reliable appliances are provided for feeding the oils, that the crank-pins, eccentrics, bearings, etc., be provided with center oilers and sight-feed cups, so that every drop of oil will go directly to the bearing surfaces without any being thrown or spattered over the engines or machinery.

For slow-speed engines, ordinary sight-feed cups, properly looked after, will give satisfactory results, but for heavy high-speed work a continuous oiling system, with the oil flowing from an overhead tank to the bearings, in streams if necessary, thence through a filter and back to the overhead tank, is the most efficient method of lubrication. From an economic standpoint, however, the success of such a system will depend entirely upon the means provided to catch the oil after it leaves the bearings.

With slow-speed engines, and in fact with all machinery that uses oil in quantities, every bearing on which oil is used should be provided with substantial sheet-steel pans, arranged, if possible, to drain the oil to some central point into a bucket or tank, from which it can be taken to the filter. If the engine is of the horizontal crank case type, care should be taken to keep the oil as free from water as possible, as water will sometimes travel along the piston rod into the crank case, and, if it is the least bit alkaline, as may be the case where compounds are used in the boilers, the oil and water together will sometimes form an emulsion which is hard to separate and lowers the quality of the oil. The above would not apply, of course, to the vertical type, such as the Westinghouse steam engine, which uses water in the crank case.

To secure economical lubrication, the first thing to do is to stop the leaks. See that every engine and piece of machinery is provided with drip pans arranged so as to catch all the oil. In a large plant where several engines are in close proximity to one another, the oil pans may be piped so as to drain the oil into a central tank, whence it can be pumped to the filter and used over again. On slow-running engines where the pressure is not excessive, and on slow-running shafting, a good grade of grease or tallow compound will often give good results, but where compression cups are used the grease should be quite soft so that it will spread freely. If too hard, great pressure will be required to feed it, and it will also tend to increase the friction load.

With large engines it is sometimes the case that the hub of the fly-wheel or a large gear wheel is fitted so close to the bearing that there is not sufficient space to fasten oil pans under the bearing, and all excess of oil will be lost. Such bearings can often be lubricated economically by packing a lump of medium hard grease on the journal, at each end of the bearing, and feeding a little oil in the middle. The grease will prevent the oil from running out too fast, and at the same time help to lubricate.

In regard to cylinder lubrication, no one can make any hard-and-fast rule as to the proper amount of cylinder oil that should be used; that will have to be determined by test and experiment. First, a good quality of oil should be provided. Second, to get economical results, make the conditions as favorable as possible. See that the steam is dry; do not carry the water in the boilers too high; do not use an excess of strong alkaline boiler compounds; and above all, do not set the piston rings out too tight. Before putting the rings in the piston, chamfer the edges off slightly with a file, for if the edges are sharp they will tend to scrape the oil off the surface.

From the lubricator the discharge pipe should extend into the center of the steam pipe, so that the oil will drop off into the current of steam. Where the engine speed is constant, there is little choice between a force-feed pump and an ordinary sight-feed lubricator. Either will give efficient and economical service if properly taken care of, but where the work is intermittent, the engine stopping and starting, as is the case with mining engines, tug-boats, etc., the force-feed pump is more economical.

To determine the proper amount of cylinder oil to use in any particular engine, first have the conditions as favorable as pos-

sible. Then gradually reduce the oil feed and note the ac ion of the valves. If they work smoothly, it is a good indication that the cylinder is all right, but if they commence to groan, increase the oil-feed slightly. In this way the minimum amount of oil that should be fed can be determined very closely. After this the cylinder head should be removed and the surface of the cylinder examined. If it looks oily, and when wiped with a piece of soft paper a stain is left on the paper, it is certain that enough oil is being used.

Another important matter in economical lubrication is in the receiving, handling and proper distribution of the lubricants. If the plant is a large one, the oil house should be provided with storage tanks of sufficient size to hold a tank car of each kind of oil. By purchasing the oil in tank cars there will be a reduction in the price per gallon and a saving in the labor of handling of the oil and the empty barrels. In a small plant where only a few barrels of each kind of oil are used a month, tanks holding from 2 to 10 barrels should be provided, so arranged that the oil can flow by gravity from the barrels into the tanks. Care should be taken to see that the barrels drain out clean.

As the empty barrels are worth from 50 cents to a dollar each, they are worth saving, and should be piled up in a cool, dry place until a sufficient number have been accumulated to make a carload. Before being loaded into the car for shipment back to the works, the hoops should be driven up tight so that there will be no danger of their coming apart and the barrels falling to pieces. The credit for the empties is based on their condition on arrival at the barreling station, and the amount paid is quite an item in reducing the lubricating cost.

It is customary in a large plant to have in charge of the oil house a man who receives and stores all lubricants, issues and charges them up to the various departments, keeping a record of the amounts given out in a book or on suitable blank forms. There are two good methods for limiting the daily amount of lubricants for each department. One is for the chief engineer or master mechanic, when making his daily rounds, to give each engineer an order for his day's supply of oil and grease. In this way he knows if the amounts required are increasing or decreasing. Another is to draw up an allowance sheet showing the amount that each engine room or department can have per day or week with the proviso that if, for any reason, it is necessary to have more than the regular allowance, a written order must be presented to the man in charge of the oil house or the storekeeper.

In a small plant the storekeeper often has charge of the oil house, opening it for half an hour in the forenoon and half an hour in the afternoon, so that those who need lubricants can come or send for them during these times. At the end of the month the storekeeper totals up the amounts of lubricants used in each department and engine room on special blank forms, and these amounts, when multiplied by the price per gallon or pound, will show the total cost for lubricants for the month. By this means it will be shown if the cost is increasing or decreasing in any particular department.

It has been found to be an excellent plan to give the engineers and heads of departments a copy showing not only their own consumption and costs, but the cost of the other engine rooms. This tends to establish a rivalry among the men, each trying to improve his practice and reduce the cost. It also tends to prevent them from wasting their supplies.

Reduction of Cost.

It is unquestionably true that nearly all plants spend far more than is needed for lubrication. This is due partly to wasteful methods in their use, partly from using lubricants unsuitable for the purpose required, and often to paying higher prices than is necessary.

The first mentioned can be prevented in a great degree by the introduction of systematic methods of issuing the lubricants and charging them to the different departments so that one can tell just what each engine room and department is costing and note if the cost is increasing or decreasing, by the introduction of more economical appliances, equipping the engines with pans and filters for recovering the waste oil, by self-oiling bearings for all line and counter shafting, etc.

In regard to more suitable lubricants, we will say that in many plants there is often a large amount of slow-speed machinery, on which, owing to its construction, it is not practicable to recover any of the oil used, in which case a good grade of what is known as dark lubricating or black oil will often answer as well as the more expensive oils. As illustrative of this, we have in mind a works that was using large quantities of an expensive grade of cylinder oil on its machinery where a heavy machine oil would have answered equally as well. In this particular case a saving could be effected amounting to over $2 000 a year.

Most important of all is to be able to purchase good lubricants at the lowest prices.

This can only be done with any degree of satisfaction by buying on specifications, submitting copies to several oil dealers, asking for bids and awarding a contract for a year's supply to the lowest responsible bidder. Of course we know that it is the practice of some oil companies to decry the use of specifications. One might as well expect the manufacturers of steel rails or cements, or the builders of engines and boilers to make the same claim as regards their products, or architects and contractors in regard to the construction of buildings. On the contrary, there is not a steel concern, cement works, engine builder or firm of engineers in the country to-day who would make such a claim. In regard to specifications, the writer will say that he has had about five years' experience with them, first while oil inspector for a large steel company operating about forty large mills, and also with many paper mills and other manufacturing companies in the New England states during the past year, and he has never known of a case where such oils have failed to give perfect satisfaction. Take the case of cylinder oils. For many years the oil dealers who sold their trademark brands at fancy prices fostered a belief among superintendents and engineers, amounting in some cases almost to a superstition, that there was something especially intricate or mysterious about the manufacture of cylinder oil, and if a consumer would have the temerity to use a cheaper grade of oil that he would encounter all sorts of trouble, cut and scored cylinders, etc.; while the fact is there is nothing to any cylinder oil except a petroleum cylinder stock of the proper quality compounded with a certain amount of some fatty oil. In the matter of engine and machinery oils, spindle oils, etc., it is simply a matter of knowing the conditions and requirements in a plant and drawing up specifications for such oils as will fulfill these requirements.

Grease.

Greases have their uses and can often be used with good economy, but, on the other hand, they also have their limitations as lubricants. Where the speeds and pressure are low, if they are of the proper consistency and fed to the bearings by suitable compression cups, they often give excellent results.

Greases are what is known as "plastic lubricants"; their particles have far less tendency to free movement than is the case with oils.

Many greases have as their base a petroleum oil combined with some animal fat, the whole solidified by combining them

with a solution of caustic soda, lime water or other alkalies, making a plastic compound that will vary in its lubricating value according to the proportions and the quality of its component parts. While greases have certain advantages as regards cleanliness, ease of application, etc., yet if used on general mill and factory machinery they will tend to add to the friction load over what it would be if oil were used.

One of the best illustrations of this in the writer's experience came as the result of a series of tests to see just what this would amount to in the case of the plungers of water-works pumping engines. The first test was made on a vertical compound pumping engine running under a constant load and at 20 rev. per min., having 4 plungers, two being $31\frac{1}{2}$ in. in diameter and two 22 in. in diameter, all having a uniform stroke of 64 in. The plungers were packed with square hemp packing, which had been well soaked in oil before being placed in the stuffing boxes, and several times a day the plungers were swabbed with oil. Two sets of indicator cards were taken. The first with the plungers lubricated with oil showed the engine to be developing 762.67 h.p. The plungers were then smeared with soft grease and time enough given to allow it to become well soaked into the packing, about one hour, and another set of cards taken which showed the engine to be developing 835.17 h.p., making an increase of 72.5 h.p., or over 10 per cent. We could not believe that there could be so much difference, so we repeated the test on another engine of the same size, make and h.p., with the same results. Figuring from a coal consumption of 2 lb. of coal per h.p. per hour, the increase would amount to 145 lb. of coal per hour, or 3 480 lb. per day of 24 hr. As there were eight engines of this same size and make, this would make a total increase in the friction load of 580 h.p., and an increased coal consumption of 27 840 lb., over 13 tons per day, so that in this particular case grease would have been a very expensive lubricant to use.

On the other hand, there are places where grease is the only lubricant that can be used. For instance, in rolling mill work, owing to the nature of the duty and the construction of the machinery, it is the only lubricant that can be used successfully. On rolls used for rolling rails, structural steel and in what we know as merchant mills, the journals or necks are kept flooded with water, a saponifiable grease must be used, that is, one containing a large per cent. of fatty oils, so that it will adhere to the wet surfaces.

In sheet-steel and tin-plate mills where it is impracticable

to use water, and the journal or neck temperatures often go over 400 degrees, a dense grease compounded with a large per cent. of high flash test petroleum oil must be used.

DISCUSSION.

The Chairman (Mr. F. W. Dean). — A great deal has been done within a comparatively few years in regard to the economical use of oil on engines for stationary purposes and on locomotives. I remember a number of years ago — I haven't paid much attention to the matter for years — when the oil consumption of locomotives was rated by the number of miles they would run per pint of lubricating oil. At that time the Lake Shore & Michigan Southern Railroad was the most economical in the use of oil, running some 25 miles per pint of lubricating oil, while many other roads were running from 8 to 15, and it was quite a mystery to know how the Lake Shore road, which ran through quite a sandy country, was able to do so well. In 1889 and thereabouts, and about the time the Old Colony Railroad took the Boston & Providence, the record on that road was, if I remember rightly, 9 to 12 miles to the pint. While the Park Square Station was in use the locomotives that took out the express trains used to back on an outside track at the left side of the station to take baggage and express cars, and there the oiling was always done. If anybody had dug up the oily earth that was under a portion of the track and squeezed it out, he could have made a small fortune on oil. Most of the oil went on the ground. After the Galena Oil Company took the matter up — that was after the New Haven Company took the road — there was quite a change. I am under the impression that they made a guarantee of oil consumption, and they began to increase the mileage per pint of oil and went far beyond the former Lake Shore rate. How it is now I do not know. In stationary engine plants the old-fashioned way was to lubricate the engines and make no effort to recover the waste oil. Now it is the regular thing to recover oil, filter it and use it over, so that the new oil required is simply a make-up supply.

Mr. Francis H. Boyer. — I am sure we are under an obligation to Mr. Davis for the valuable information he has brought us. But from the standpoint of the operating engineer, I think there is one story I'd like to tell that bears on this question, where we made a saving of about 90 per cent. in our cylinder oil used. We were operating a plant in which there were two cylinders 32 in. in diameter, and 32-in. stroke Corliss engines, work-

ing under 90 lb. of steam. In operating these engines at regular periods there would be severe chattering on the valve seat, also in the steam cylinder, and we had valve stems twisted from this same cause. When the periods of chattering occurred the attendant would open his lubricating cup and permit a stream of oil fully $\frac{1}{4}$ in. in diameter to flow into the cylinder, often feeding a quart cup full of oil in a few minutes.

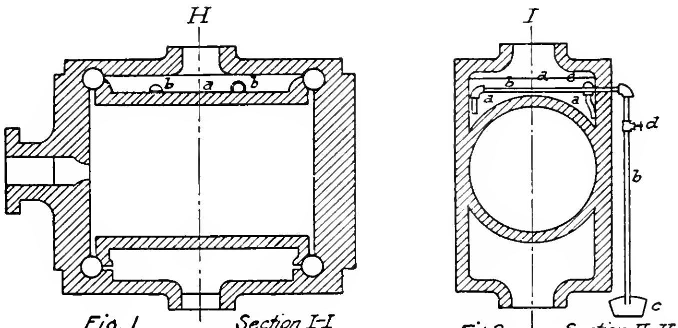

Fig. 1 Section I-I Fig. 2 Section H-H

Upon examination we found that a large chamber was formed by the exterior walls of the cylinder and the walls of the steam chest, as shown in *a*, *a*, *a* in accompanying sketches, this water rising until it flowed over the valve seat, shown at *e*, Fig. 2. This water came from the condensation from the steam in transit between the steam boilers and the engine, a distance of approximately 60 ft.

It was evident that this water must be trapped off. Not wishing to make holes for pipe connections on both sides of the cylinder, we had piping put in as shown at *b*, *b*, *b*, the end of the pipe in the pocket being open. At *d* we placed a valve and terminated our piping in steam trap at *c*. The cavity formed around the cylinder was of size to hold fully 15 gal. of water. Upon completion, we started the trap on the first engine, the trouble ceased, and we had no difficulty afterwards.

One thing more, a remarkable thing in reference to our steam plants. In the last few years there has been a change in the steam pressures that are carried, and this has a direct bearing on the amount of lubrication used. Not long since I came from Norfolk on a steamer with three cylinders and one shaft operating under 175 lb. per sq. in. of steam. Upon inquiry I found the consumption was about one quart of oil the whole distance on her three cylinders. The temperature of the entering steam at 175 lb. pressure per sq. in. is 370.8 degrees. At this tem-

perature we are approaching the burning point of oil, and as a result a sediment of carbon will form in the cylinders which is very detrimental to their operation. So that I think a good deal of economy in the use of locomotive oil to-day may be due to the use of steam at different temperatures from what was formerly used. Not long since I was talking with Mr. J. B. Herreshoff — perhaps it was ten years ago — and he called my attention to the fact that on his torpedo boat, the *Cushing*, which was then building, and operating under 250 lb. steam, he used no oil. "Why," he said, "I dare not use any oil at all in my cylinders for fear of the carbonization which will form on the walls of the cylinder." Now we are changing in engineering, and it may be that this excessive economy we are getting to-day in the use of oil in our engines may be due to the use of 180 to 225 lb. of steam without lubrication.

THE CHAIRMAN. — I want to take the liberty of calling on Professor Hollis to tell us something about the methods in the navy of lubrication, both for cylinders and other bearings.

PROF. IRA N. HOLLIS. — I went through the lard and sperm oil period thirty years ago, and then, before leaving the navy, reached the modern period of using no oil at all in cylinders. Not only is the use of lard oil, or any animal or vegetable oil, in the cylinders for marine purposes bad for the cylinders, but it is also destructive to boilers, as it goes through the condenser, is fed into the boilers and is very bad on steel, both on account of corrosion and of deposits that harden under the action of the fire. I recall a type of boilers which the engineer-in-chief of the navy used to tell me was an 8-in. boiler. It was really 8 ft. in diameter. There were several ships built in which that boiler was used, and I think only ten of the boilers out of about fifty escaped damage in the course of two or three years on account of grease deposits. Inasmuch as I was on the ship that had the fewest accidents, I put the accidents entirely to the use of olive and sperm oil in the cylinders. We found that the steam acted on it and formed it into balls which collected in the condenser, or the hot wells, and then passed into the boilers, where they caked on the heating surface.

But regarding the use of oils on modern vessels, I don't believe it is possible to run a horizontal cylinder for marine purposes without oil. I tried it a number of times. But in the majority of upright engines there is no necessity of using oil. In the battleships — those now going around to San Francisco — they use no oil at all in the propelling cylinders, and they are

now forbidding the use of oil in all engines. In that connection I can, perhaps, bring out one point of greater interest than the use of oil in the navy, and that is the effect of oil on the inside of the cylinder. Mr. Davis was good enough to refer a little while ago to the increase in horse-power due to a change of oil — if I understood that right.

Mr. Davis. — What I referred to was an experiment to see what the difference was between using oil and grease on the plungers of water-works engines. We found we got a greater horse-power by the use of grease than we did when using oil, this increase in horse-power being due to increased friction.

Professor Hollis. — In the steam cylinders?

Mr. Davis. — No, the water plungers. We got a greater indicated horse-power by the use of grease than without.

Professor Hollis. — Now, this brings out another point in relation to the use of oil. I am not violating any confidence, I think, in stating the experience of one of our firms who agreed to build some vertical engines on a limited consumption of steam. The engines were to be run without oil in the cylinders. It was found on trial that without oil the consumption of steam exceeded the ordinary consumption with oil in the cylinders by nearly 20 per cent. Now, the question is, To what was that due? The question put to me was, What was the difference and why should there be so great a difference? Was it due to the fact that oil acted as a non-conductor on the surface of the cylinder and in that way prevented initial condensation? Was it due to a reduction in the leakage losses? Was it due to the fact that, inasmuch as these cylinders are used with condensers, that some of the oil on the stuffing box prevents a leakage of air into the exhaust? Was it due to the fact that there is 20 per cent. friction in the piston and stuffing box of the steam cylinder? I know very little about the effect of oil as a non-conductor of heat, and I have never conducted any experiments for the purpose of determining it. I doubt very much whether the use of oil will prevent leakage of steam from one side of the piston to the other. I am quite sure the use of oil would give a higher mechanical efficiency. Perhaps Mr. Davis would be good enough to tell us if he knows anything about the use of oil in a cylinder and its effect upon initial condensation.

Mr. Davis. — I never heard that point brought up before. It is very interesting. I shouldn't think, though, it would have very much effect.

Professor Hollis. — The people who brought it up found

the question a very important one in connection with their contracts.

A MEMBER. — I'd like to ask what was the pressure of steam for marine purposes?

PROFESSOR HOLLIS. — The steam was all the way from 100 to 150. I have never had the responsibility for a horizontal cylinder where I would trust it without oil for marine purposes. I don't know how that is for stationary purposes. The last engine I was with — the one where I really attempted to try the thing out — we had two cylinders, one 85-in. cylinder and the other a 42-in. cylinder, with a 42-in. stroke, and two piston valves on each cylinder, the engines being 3 500 h.p. each. We used plenty of oil. We had to. One of the things I noticed was that cutting down on the oil considerably gave us a good deal of trouble with the low-pressure cylinder in starting. There was always plenty of water which pounded for hours under such conditions. Now, a person going to sea, and especially going over the bar at San Francisco, with a low-pressure piston cutting up that way at every stroke, knowing there is water in the cylinder and wishing to get it out, is not going to experiment very long. Then, too, the piston valves, the low-pressure piston valves, had snap-rings in them $\frac{5}{8}$ in. square and valves 28 in. in diameter, two for each cylinder. Steel was used in the rings instead of cast iron, and a great deal of oil was required to keep them from cutting. I think they ran dry very often. At the end of six months I took one of the rings off and examined it. It was still $\frac{5}{8}$ in. wide, but its thickness varied in different places between $\frac{5}{8}$ and $\frac{1}{8}$ in. That is, it had gotten down to a thickness of $\frac{1}{8}$ in. in places. Of course, the rings were promptly replaced. The excessive wear may have been due to the difficulty of oiling.

I don't like to prolong this conversation, Mr. President, but there is another point that was taught me when I was a cadet at the Naval Academy; that was, when once you started to use oil in a cylinder, you never could stop it. For twenty years I believed that. I think now it is a mere superstition. I am perfectly satisfied that you can take any cylinder and use oil in it, and if you have a little patience in getting rid of the oil, you can use the cylinder without oil just as well as if you had begun without oil. I am inclined to think if there is a little bit of oil at the start it will give you a good surface and you can run without it afterwards.

THE CHAIRMAN. — I am glad to hear Professor Hollis speak of the superstition that if you brought an engine up badly

by the use of oil you must keep on. Before we go further I should like to ask him if he knows whether there are any steamships in the mercantile marine — transatlantic ships — running without cylinder oil.

PROFESSOR HOLLIS. — I think so, Mr. Chairman. I have been in the engine rooms of a number of merchant ships that do not use oil in vertical cylinders. But I can't remember the names of the lines. I have seen cylinders run without oil, and I don't see any reason under the sun why a vertical cylinder should not be run without oil. But I still believe that oil ought to be used in a horizontal cylinder on account of the weight of the piston. You get into trouble as soon as you attempt to run a horizontal engine without oil.

MR. DEAN. — Mr. Davis has spoken about the advisability of beveling the piston-rings of cylinders to help along matters. That brought to my mind some things that I heard in Fall River several years ago. At one mill — I have now forgotten the name — where there was a large horizontal compound engine, for a long time it gave so much trouble with the low-pressure cylinder that the head was taken off and the valves at that end disconnected, and the cylinder was run single-acting. Every now and then, with a squirt gun, oil was squirted into the cylinder. Finally an engineer from another mill suggested that if one of the packing rings from the piston were taken out — there were two rings some inches apart — there would be no further trouble. His advice was followed, the cylinder head put on and the trouble stopped. In other words, one packing ring in the cylinder probably scraped all the oil away, so that the lubricating effect was greatly diminished. I should be glad to hear from anybody else on the subject.

MR. FRANCIS H. BOYER. — I would like to make another reply to some remarks the gentleman has made. Many years ago, before the introduction of mineral oils for lubricating, we used the best lard oil for the lubrication of cylinders, and I know from experience that it was disastrous. Take the best steam cylinder and valve seat and lubricate them with lard, and in about nine months you will find that the whole face of the metal becomes spongy. Holes are eaten in it, bolts will be destroyed. This is due to the action of the sulphur in the decaying process of lard oil, the sulphate of hydrogen you get in all animal substances, which is rapid in its attack on iron. I have seen many cases where the surface of the metal was absolutely destroyed, honeycombed like a loaf of bread, as a result of the use of animal oil.

MR. DAVIS. — I can bear out the gentleman's statement in regard to that. I commenced as oiler on lake steamers in 1879. We were then using tallow in the cylinders. My first experience as oiler was on a side-wheel beam engine boat. We kept a can of melted tallow on top of the cylinder. Every once in a while we'd have to fill the cup up, and we always had to be careful to open the cup when the piston was going up, so the vacuum would suck the tallow in. When we'd take the cylinder head off we'd find it all corroded, just as you say, — threads eaten off, the surface of the follower-plate corroded and honeycombed, and inside the piston we'd find full of little balls. The tallow and iron rust combined with dirt caused this accumulation in the form of balls. I had been sailing two or three years before we commenced to use compounded petroleum and animal oils.

MR. BOYER. — A little story about animal oil may be interesting and will but take a moment, if you will permit me. Lard oil, as a rule, is made from the refuse of hogs mostly, hogs that arrive dead from suffocation or other causes in shipment. Before rendering begins a certain amount of decomposition has already taken place, which means that the flesh and bones are passed back into free gases. When the rendering is completed the greases vary in color from mahogany brown to a light yellow. After a long series of experiments we found that the color of the grease was due to the iron that had come from the receptacle in which it was rendered. If we took the same quality of material and rendered it in any receptacle where it didn't come in contact with iron (for instance, a wooden pail; we first started in aluminum pails), we had just as beautiful white lard as any one would wish to see, and made out of hogs which were rotten. You can imagine what it meant, thousands of dollars to these packing men, where they turn out 4 000 or 5 000 lb. daily, varying from $\frac{3}{4}$ to $1\frac{1}{2}$ cents a pound difference in price. Now you can see how that oil affects machinery. Wherever there is a joint, wherever the sheets are riveted together, it will get in and eat those rivets off; that is due to the sulphur which results from the decomposition of animal substances. That is the reason why it is not advisable to use animal oil for any practical purposes in contact with iron surfaces.

A MEMBER. — In a plant where the lubricant is used over and over again, what percentage of it is lost? There must be some loss.

MR. DAVIS. — You mean the loss that takes place by evaporation or something like that?

MEMBER. — Yes.

MR. DAVIS. — I think that would be almost negligible unless the bearings become overheated. Under ordinary conditions the loss due to leakage in handling is the only loss worth considering. There is always some loss due to that; some spattering out over the engine frame, leaking through the oil screens and so on. But the amount of loss due to evaporation or anything like that would be negligible. Take an engine oil that would have a flash test of 400 degrees, used on ordinary engine bearings would never be subjected to a temperature high enough to cause evaporation to take place.

MR. FULLER. — May I ask Mr. Davis whether this filtration of which he speaks is anything more than straining?

MR. DAVIS. — That is all, straining, and generally the simpler the better. All that is necessary is to get the dirt out of it.

THE CHAIRMAN. — Mr. Davis, what is the best filtering material?

MR. DAVIS. — I don't know that anybody can tell what is the best. All sorts of things are used. Three different types of filters use cotton flannel. Some filters use cotton waste as a filtering medium. I have seen filters that used excelsior as a filtering medium with very good success. The dirt in the oil would adhere to the wood and shavings and the clean oil would pass through. Sponges have been used as a filtering medium. You can take ordinary engine oil and give it time enough and it will precipitate nearly all its dirt in the tank. But if you want to filter as quickly as possible, the best thing is to put it through some filtering medium.

MR. IRVING E. MOULTROP. — I wish to say a few words in reference to Mr. Boyer's remarks regarding the possibility of eliminating cylinder oil on account of the higher steam pressures which are being used at the present time. I believe that the higher steam pressures in present use do not necessarily tend to dispensing with cylinder lubrication, although in some cases the higher pressures may make it possible to reduce the quantities of oil used.

In our turbine station at South Boston we are running 175 lb. boiler pressure, superheated at the boiler to about 150 degrees fahr.; allowing for a reasonable drop in temperature between the boiler and the steam cylinders, we get a total temperature at the cylinders of about 500 degrees.

Our auxiliaries are mostly horizontal machines, and we

find it desirable to use a certain amount of cylinder oil on all of them. Of course when these machines are started up after having been shut down for a certain length of time, and the steam parts have become fairly cool, there is considerable condensation in the cylinders, but after they have been running for a short time and thoroughly warmed, there is doubtless very little condensation, yet we have never felt that it would be good policy to dispense with cylinder oil, even though the condensation was entirely eliminated.

Mr. Theo. O. Barnard. — I should like to ask, in connection with Mr. Moultrop's question, if Mr. Davis can give us any information on desirable oils for use with heavy duty engines using superheated steam. We find there are a great many heavy-duty engines, horizontal engines in cotton mills that have ammonia compressors that are now using superheated steam, and operating engineers have had in many cases a great deal of difficulty in properly lubricating the walls of the cylinders with the various oils that have been suggested for the purpose.

Mr. Davis. — I should say that for use with superheated steam an oil ought to be of high flash test, that is, 550 to 575. There is such a thing as getting the flash test too high. Of course, any manufacturer of oils, in order to get a higher flash test, has to reduce the oils down to drive off the more volatile products. Consequently, as the flash test increases, the density increases also. It becomes more viscous, and while viscosity is a good thing for an oil to have, there is such a thing as having too much viscosity, so that it doesn't atomize and spread out well. It becomes tarry. So you have to strike a happy medium. I should say 550 to 560 or 570 degrees would be sufficient flash test. If you have perfectly dry steam it may be possible to use only a straight petroleum oil. But take a compound engine, when you come to lubricate the low-pressure cylinder you will find a good deal of condensation. There is a big drop in temperature and a corresponding increase in condensation. In order to secure lubrication under those conditions you have to have an oil compounded with animal fat to make the oil stick on to your surface. That is all the animal fat is used for. Petroleum oil has no affinity for water, and if used alone would wash right off. The best animal matter to use is what is known as acidless tallow oil, although some companies use neat's-foot oil.

DISCUSSION — Continued at Meeting held February 12, 1908.

Mr. James F. Monaghan (*by letter*). — That part of the discussion referring to the running of steam cylinders without lubrication brings to mind a pair of horizontal engines which might be of interest to refer to. It is customary in nearly all bleacheries and dye works to use low-pressure steam for boiling and drying the cotton cloth. This steam is reduced from high to low pressure in some plants, and in others is taken from the exhaust steam from the engines working against a back pressure of 5 to 10 lb. per sq. in. When this exhaust steam is drawn into a kier in which the cotton cloth is to be boiled in alkaline liquor for the bleach, it of course carries along with it a part of the oil from the cylinders. This oil is objectionable, for the purpose of the alkaline boil is to remove all oils, fats, etc., in the cloth.

In the case of the two engines to which I refer, the installation was started with oil used in the cylinders, but this idea was later changed and these engines ran for about ten years without any cylinder lubrication, in order to obtain an exhaust free from oil. At the end of this time the use of oil in the cylinders was resumed, and the engines are to-day running lubricated. Before the internal lubrication was resumed, however, it was necessary to rebore the cylinders and fit new rings to the pistons. These engines were of the Corliss type, each 36 in. diameter of cylinder by 60 in. stroke, running 60 rev. per min., with a steam pressure of 90 lb. per sq. in. They were coupled together on the same shaft, at times running together, and often with one side or the other disconnected.

In another bleachery, I know of a pair of Corliss engines of about 350 h. p. each, exhausting against a back pressure of 8 lb. per sq. in. with both cylinders lubricated, and the exhaust steam is used for boiling in the bleaching kiers. Here no attention is given to the oil carried in with the exhaust. The amount of cylinder oil used per cylinder is one pint for every 3.5 hr. run, and these engines are 26 in. diameter of cylinder by 48 in. stroke. One engine runs 76 rev. and the other 62 rev. per min., with the oil consumption the same in each case. The steam pressure is 90 lb. per sq. in.

Mr. W. M. Davis. — I will say that while I have known of cases where horizontal slide valve engines were run without cylinder oil, this is the first instance I have ever known of a Corliss engine running without cylinder oil.

The Chairman. — It is the first case I ever heard of.

Mr. Davis. — I remember in Pittsburg, where I lived for a

number of years, that there was a plow works in which they had an old horizontal slide valve engine that made, as I recollect it, about 50 or 60 rev. per min. I think it was about 24 in. in diameter, with perhaps a 36-in. stroke. I don't think the steam pressure was more than 60 or 80. It was a very old-fashioned plant. That engine never had a drop of cylinder oil in it. The old engineer who had been on the job ever since the plant started, I think, said there was no place to put cylinder oil in, and he never used a drop. He said he wouldn't use cylinder oil in any cylinder. But he never worked anywhere else. I don't know what he would do if he went as engineer in some of the rolling mills I know of around Pittsburg.

I do not doubt but what horizontal engines can be run perhaps successfully without cylinder oil if soft metal rings are put in or tail rods used to support the piston from the bottom of the cylinder, and grooves cut at the ends of the valves so that there will certainly be a good flow of moisture in between the valve and the valve seats, especially a Corliss engine. It is just possible that large engines could be run without the use of cylinder oil. But the chances are there would be more friction than there would be with oil. Perhaps the loss from increased friction would offset the saving.

The Chairman. — Where you speak of this lubrication, you mean the bearings?

Mr. Davis. — No, the ends of the valves where they rest in the castings. They should be so grooved that the steam will flow in. It will probably be in such shape that there will not be any great amount of wear; that is, it will not stick. But in that case Mr. Monaghan speaks of, the engine was run for ten years without the use of oil, if I understand him right.

The Chairman. — Yes.

Mr. Davis. — He said the engine was run ten years without the use of oil, and when they began to use it they found it necessary to rebore the cylinders. Well, I have known many cylinders on which oil was used in such large quantities that it was necessary to rebore. Sometimes it is necessary more than once in the course of a year.

Mr. W. G. Starkweather. — That question of grooving mentioned by Mr. Davis is important. I remember an instance near this city where we had a heavily-loaded vertical cross-compound engine on which the high-pressure crank pin caused considerable trouble, despite all the oil that could be put on it. After some experimenting, and just as the owners had

about decided to put in a new pin, the right combination of grooving was found, and that pin is running satisfactorily to-day without other change. The new grooves distribute the oil to the right place. That was the whole secret of it.

Mr. Davis. — I can readily appreciate that. I know cases where they had the same trouble that you speak of.

Mr. Starkweather. — It might be interesting to state what is being done on the large gas engine cylinders to-day in the way of internal lubrication. In our gas engines we are obliged to use a grade of oil that will stand the high heat of the combustion. It is pumped in on top, at each end of the stroke, just as the piston reaches the hole, so that it is carried back and forth on the piston between the rings and flows around it and is distributed as it flows, thus lubricating the cylinder walls. The pistons are all supported by tail rods.

As well known, the lubrication of bearings, pins, slides, etc., has been threshed out pretty carefully, and the oiling apparatus of an engine is well developed. The engine to-day also has guards over the eccentric crank and at the slides, so that the oil is put on freely and kept from getting away, and can be collected, filtered and re-used.

The Chairman. — I notice in your paper, Mr. Davis, that you speak of the small amount of oil that is lost in modern methods of lubrication and prevention of waste. But of course there is always being added a certain quantity of new oil. Do you know what relation there is usually between the make-up supply and that which is actually run on the bearings?

Mr. Davis. — I have no data that will give you anything authoritative on that. No two cases are alike. Just as Mr. Starkweather says, they are providing shields and pans and everything to retain the oil. That is the secret of economical lubrication, — to take every means possible to prevent the oil from being lost. It does not matter how much you put on the bearings, if you can recover 99 per cent. of it, your loss is only 1 per cent., no matter if you use a barrel an hour. On the other hand, if you only use a gallon an hour and lose all of it, your loss is 100 per cent. So in modern engineering it is customary to go to considerable expense to prevent these oil losses. But there is always some loss from wiping up, but just how much I could not say. Even where the engines are very well protected with shields, pans, screens, etc., in wiping up around the machinery there is a little loss.

I was at quite a large paper mill some time ago, where they

make a point of gathering up all the oily rags. They use rags there instead of waste, and put them through one of these oil- and waste-saving machines. While those rags do not seem to be very oily, that is, thickly saturated with oil, yet they recover over a barrel of oil every week by so doing. Besides, they get the use of the rags again for wiping. They have a man that does some other work and every so often he gathers up all these oily rags and puts them through this machine. And then the oil is filtered and used around the plant again.

Mr. Starkweather. — Is that machine you speak of a press?

Mr. Davis. — No, it is a centrifugal machine. There is a steam pipe in connection with it, and the hot steam and centrifugal action extract the oil from the rags and waste.

The Chairman. — There has recently been brought out, at least it is new to me, an oil filter which works by centrifugal action. It is a very small affair compared with the ordinary filters.

Mr. Davis. — I think it is the same company that makes that oil- and waste-saving machine. I will say that some years ago I made some experiments in cleaning oil by the centrifugal process. I used an ordinary creamery separator and got excellent results. I took some of the dirtiest oil I could find in the bottom of the waste oil tank — it was almost black in color — and put it through this creamery separator and got it out as clean and bright as when it came from the barrel. But the separator very quickly clogged up and it was hard to get it clean again.

The Chairman. — Was it as clean as Mr. Boyer's lard made out of rotten pigs?

Mr. Davis. — It seemed to be so. They got pretty clean lard, when they treated it right, from rotten hogs. It is too bad that Mr. Boyer is not here to-night to tell us more about it. A company has recently brought out a centrifugal oil filter, a clarifier they call it, but I have not seen it yet nor do I know how good it is.

A Member. — Can Mr. Davis give us any idea how often oil should be used over again?

Mr. Davis. — Oh, yes, as long as you can catch it. Take some of these small-speed engines. They have a small tank and pump arrangement connected right on the engine, and the oil keeps circulating over and over again. It goes over the bearings, thence into this little tank, which has a strainer in it, and from there is pumped back over the bearings again.

The Chairman. — Is there nothing in the use of oil that injures it at all?

Mr. Davis. — In the case of the high-speed engines there is but little chance for dirt to get into it. Everything is protected. I have seen oil that had been in use several weeks without any being added to it, and it looked as clean as when it was put in.

A Member. — Does oil actually wear out, or simply waste?

Mr. Davis. — Simply wastes.

A Member. — Is there no such thing as wearing out?

Mr. Davis. — Some years ago, before it was the practice to filter oil as it is now, many engineers claimed that oil was not fit to use after it had been used once; "that the life was worn out of it," and so on. I know when I first went to the American Sheet and Tin Plate Company as oil inspector and commenced to introduce economies such as the saving of oil by filters, etc., that was a common idea among some of the engineers, "that oil once used might be good enough to use on mill machinery, but not to use on an engine."

A Member. — Well, some of the oil used on turbines is quite light in color. But after being used, even when it is filtered, it has changed its color and consistency quite a little.

Mr. Davis. — Yes, it will usually get a little darker.

A Member. — Is that simply iron?

Mr. Davis. — It may be due to metallic wear, but it is not enough to affect the quality of the oil; it only affects the color.

A Member. — It is wholly the color? Nothing detrimental to the oil?

Mr. Davis. — Nothing.

A Member.— This is why I asked the question: I had a turbine engine and the Standard Oil man who furnished the oil said it should not be used more than fifteen times in 24 hr. This plant has a duplicate filter. He wants one filter to be used one day and the other to be used the next day, the oil to rest meantime. But we are using it about thirty times in 24 hr. It is a Curtis steam turbine plant and we get emulsion in the oil.

Mr. Davis. — If there was water in the oil that would give it time to settle out; perhaps that was the reason.

A Member. — He is trying to get rid of emulsion, which is very considerable. But in the design of the General Electric plant at Schenectady, he advised not to use oil more than fifteen times.

Mr. Edward B. Richardson (*by letter*). — In the recent contribution on "Economical Lubrication of Large Plants" by

Mr. Davis, and the consequent discussion, but slight mention was made of lubrication in turbine plants. Thinking that the experience in such a plant of 2 500 kw. capacity of Curtis turbines might be of interest, the following outline is presented:

In the plant in mind two 1 000 kw. and one 500 kw. turbines are installed, having, as is usual, oil lubrication for the steady and step bearings for all units and in addition for the larger two oil governor control.

Two 15 gal. per min. oil filters are installed, having each a storage tank of 400 gal. capacity. The oil returning from the turbines by gravity enters the filters at one end, rises through water, which can be heated to about 200 degrees fahr. by a steam coil and through trays of excelsior. It then passes through two more similar compartments, except that no steam coils are provided.

After the cleansing done thus it flows into the storage compartment, where it is cooled by contact with a pipe coil of cold water. From the storage compartment it flows on to the oil pressure piston pumps, which distribute it at about 500 lb. per sq. in. pressure to the supply piping system.

Considerable trouble has been experienced by the formation of a thick, milky emulsion, which occurs in more or less quantity. This emulsion has occurred with two different oils, and the opinion is advanced by the company furnishing the last lot of oil used that the trouble is due to too frequent use of oil, thus not allowing opportunity for clarifying.

The oil is guaranteed a pure petroleum distillate, with no compounding and with blending only sufficient to maintain its uniformity. Analysis of the water used in the plant shows no chemical property which would produce a chemical action.

The explanation of the formation of the emulsion is as follows: Oil having a natural tendency for holding a certain amount of water, the churning effect when it passes through the pumps causes a more or less perfect mechanical mixture, thus producing the emulsion. A certain small per cent. changes composition by chemical action. It is claimed that if the oil is allowed time for settlement, the emulsion, except for this small per cent. (about one), will separate into its component parts of oil and water.

The manufacturer claims that no oil should be given harder service than by using it more than fifteen times in 24 hr., whereas the oil in this plant is re-used about thirty-three times with all units operating, the quantity per minute being 12 gal. He claims

that if on any system one filter is used for 24 hr., and then the other is used for a similar length of time and with proper heating, the emulsion will disappear, except for this small per cent. of changed formation.

Since oil engineering for this kind of plant with the use of oil at high pressures and in bearings where the circumferential speed of the shafts in the bearing may be as high as 2 500 ft. per min. is a new problem, the machine as well as the oil manufacturers have to take a hand in solving the problems arising.

It is the opinion of the oil manufacturers supplying the oil in this case that more care must be given and a more extensive system designed than has been required in continuous oiling systems for engine plants.

Since the system in mind has not been changed as suggested, certain features having just been reported upon, it is impossible at this time to give information in regard to the solution of the problem, but the above is contributed with the thought that it may furnish some member with information for thought, or may afford him help should he be working on a similar problem.

[NOTE. — Discussion of this paper is invited, to be received by Fred Brooks, Secretary, 31 Milk Street, Boston, by July 1, 1908, for publication in a subsequent number of the JOURNAL.]

SOME HISTORICAL FACTS AS TO THE DISCOVERY AND USE OF THE MAGNETIC NEEDLE, AND SOME FACTS FROM THE AUTHOR'S EXPERIENCE WITH THE COMPASS AND JACOB STAFF IN LAND SURVEYING IN LOUISIANA.

By M. P. Robertson, Member of the Louisiana Engineering Society.

[Read before the Society, December 9, 1907.]

Gentlemen: I have chosen for my theme a subject with which I have been made familiar from long experience in practical field work, rather than travel the beaten paths of levees and high water on the Mississippi River and its tributaries, the latter subject having been diligently threshed and winnowed by my colleagues engaged on river work, so that bags both of tares and wheat were scattered broadcast throughout the engineering world.

Historical. — The earliest references to the use of the compass were Chinese. Just as we got the art of roasting pigs from Hoti's promising son Bobo, and gunpowder from the Chin-Fous and Goiden Chops, the great historian Ah-sam has it that in the sixty-fourth year of the reign of Ho-Ang-Ti, 2634 B.C., the Emperor Hiuan-Yuan or Ho-Ang-Ti attacked one Tchi-Yeou on the plains of Tchoulon, and, finding his army embarrassed by a thick fog (raised by the enemy hitting the pipe) constructed a chariot for indicating the south, so as to distinguish the four cardinal points, and was thus able to pursue Tchi-Yeou and take him prisoner. Be it as it may, the Chinese, to whom we owe the rudiments of so many sciences, have always stopped at the beginning and worked backwards, for if we continue our research we find that under the Tsin dynasty of between 265 A.D. and 419 A.D. there were ships directed to the south by the needle. The Chinese once navigated as far as India. The name Ting nang ching, or needle pointing to the south, shows them again as turning their backs upon Polaris, the guide of modern navigators and surveyors; and they still reckon all points from the South Pole, as in this country they are reckoned from the North, which shows beyond doubt that we have improved on them. It is claimed that the needle was given by them to the Arabians, and by the Arabians to the Europeans.

However, the first person to bring it into notice in Europe was Marco Polo, a Venetian, born 1254 A.D., died 1324 A. D. At the age of seventeen, in company with his father Nicolo and

uncle Maffeo, he traveled through Tartary and across the great desert to Gobu and Tavgut, thence to Shoughu, where they found Kublai Khan in 1275. They were kindly received by the great Khan and retained in the public service. Marco Polo rose rapidly in the emperor's favor and was employed in various missions in different parts of the empire. Marco with his father and uncle left China in 1292 and after many adventures reached Venice by way of Sumatra, India and Persia in 1295. In 1298 he was taken prisoner in the battle of Curzola between the Venetians and the Genoese. Here he dictated an account of his adventures to a Frenchman, in a work called "Rusticiano of Pisa," which obtained wide popularity.

Flavio Gioja, of Amalfi, Naples, about 1362, is also claimed as the inventor or introducer. So also do the English claim a knowledge dating back many years before Columbus, and contemporary writers ridicule the idea of either Marco Polo or Flavio Gioja's claims. It is not unreasonable to suppose that all Christendom brought back some knowledge of Eastern science from the various crusades to the East, covering the period from 1081 to 1250. By all Christendom there is also no doubt that to Marco Polo is largely due the discovery of America, since his work on his travels to the great Khan is cited by Fernando Columbus, the son of the great Admiral Christopher Columbus, in corroboration of the idea that Asia, or, as he always termed it, India, stretched far to the east, so as to occupy the greater part of the unexplored space. The narratives are cited of Marco Polo and John Mandevelo, travelers who had visited the remote parts of Asia, far beyond the regions laid down by Ptolemy, and their account of the extent of that continent to the eastward had a great effect in convincing Columbus that a voyage to the west of no long duration would bring him to its shores or to the extensive and wealthy islands which lie adjacent.

Be it as it may, the results obtained by those who preceded Columbus are but small compared with those achieved by him. Washington Irving, in his "Life and Voyages of Columbus," Book III, chapter 11, in my opinion sets at rest the question as to the discovery of the variation of the needle. He says:

"On the thirteenth of September, in the evening, being about two hundred leagues from the Island of Ferro, Columbus, for the first time, noticed the variation of the needle; a phenomenon which had never before been remarked. He perceived, about nightfall, that the needle, instead of pointing to the north star, varied about half a point, or between 5 and 6 degrees, to the northwest, and still more on the following morning. Struck with

this circumstance, he observed it attentively for three days, and found that the variation increased as he advanced. He at first made no mention of this phenomenon, knowing how ready his people were to take alarm, but it soon attracted the attention of the pilots, and filled them with consternation. It seemed as if the very laws of nature were changing as they advanced, and that they were entering another world, subject to unknown influences. They apprehended that the compass was about to lose its mysterious virtues, and, without this guide, what was to become of them in a vast and trackless ocean?

"Columbus taxed his science and ingenuity for reasons with which to allay their terror. He observed that the direction of the needle was not to the polar star, but to some fixed and invisible point. The variation, therefore, was not caused by any fallacy in the compass, but by the movement of the north star itself, which, like the other heavenly bodies, had its changes and revolutions, and every day described a circle round the pole. The high opinion which the pilots entertained of Columbus as a profound astronomer gave weight to this theory, and their alarm subsided. As yet the solar system of Copernicus was unknown: the explanation of Columbus, therefore, was highly plausible and ingenious, and it shows the vivacity of his mind, ever ready to meet the emergency of the moment. The theory may at first have been advanced merely to satisfy the minds of others, but Columbus appears subsequently to have remained satisfied with it himself. The phenomenon has now become familiar to us but we still continue ignorant of its cause. It is one of those mysteries of nature, open to daily observation and experiment, and apparently simple from their familiarity, but which on investigation make the human mind conscious of its limits; baffling the experience of the practical, and humbling the pride of science."

I have quoted this part of Washington Irving's history in contravention of the Encyclopedia Britannica, which attempts to demonstrate that one Peter Adsigio, a Venetian, knew its use in 1269, and that it was known in Scotland in 1306. There is but little more reason for attributing the knowledge of the use of the Magnetic Needle to them than the practical use of steam to the Egyptian priests who knew how to blow a steam whistle or keep balls suspended in the air by means of a steam jet, or to Martin Luther when he advocated in a sermon in Germany that steam could be utilized instead of dogs to turn a spit for roasting meat. There are no data extant as to the first application of the compass in land surveying, but the division of the circle into 360 degrees dates back to great antiquity, probably prior to the Christian era. The knowledge of the ancients as to geometry was very great, and the solution of the area of a circle was known to Archimedes, 212 B.C. The magnet was also known to the

Greeks and Romans — its derivation is from the Greek word, "magnes," from having been found near the town of Magnesia in Lydia, — but they knew nothing of its directive force; but what they lacked in definite experimental knowledge they supplied by an abundant use of the imagination. We are told, for instance, that the magnet attracts wood and flesh; it is effective in the cure of disease; that it affects the brain, causing melancholy; that it acts as a love philter; that it may be used in testing the chastity of a woman; that it loses its power when rubbed with garlic and recovers it when treated with goat's blood, and that it will not attract iron in the presence of a diamond.

The science of magnetism made no real progress until the invention of the compass. The acquaintance of the ancients with astronomy was very advanced, and we owe to them the names of the stars in the constellations, also the observation of the planets in the heavens. Their method of determining the north, that is, the meridian, was by means of erecting perpendicularly a pole or rod; with the center of the pole as a pivot and its shadow at early morning as a radius, they described the arc of a circle; then observed at evening, when the shadow again cut the arc thus described, and joining these points by a cord they bisected the cord and from the center of the pole passed a line through the point of bisection, the line thus drawn being the north and south.

To attempt no more than a cursory glance at the subject of magnetism is all I intended, as to it are due so many scientific inventions of the age, and any attempt to go deeply into this subject would require volumes rather than pages. I cannot but feel proud that to America more than any other country is due the discovery of electro-magnetism and magneto-electricity, that have revolutionized modern science and given us a place to-day in the history of the world as first in science; and to no two men is due this great achievement more than to the late Prof. Joseph Henry of the Smithsonian Institution, who discovered that magnetism and electricity were interchangeable, and to Thomas Edison in applying this principle in the invention of the electric light and electric motor. The world, too, has to thank the magnetic needle for our cablegrams and Marconi telegraph, for the safety of our ships at sea, for our land surveys and many other scientific operations. Notwithstanding that the sea has been accurately mapped, the chronometer rated and azimuth points placed at every important port, and the "Sextant and Nautical Almanac" provided for mariners, still, when a storm or a fog is on, our great ships have to resort to the log and the

compass, that is, to navigate by dead reckoning or practically by compass and chain.

It is a common thing for those engineers who have not had any practical experience in the location of land lines to place but a cheap estimate on those who follow that branch of professional work. There is, perhaps, some modicum of justice in this, yet on the whole they are grievously wrong. Some few illiterate people are engaged in running lines occasionally, yet when we sum up the requisites of a thoroughly competent land surveyor we may well respect him. They are as follows: (1) An iron constitution. (2) A knowledge of mathematics beyond what is ordinarily required of a transitman or leveler. (3) The knowledge of a lawyer and the acumen of a detective. (4) He must know human nature and be able to control his temper. (5) He must be able to impart sufficient knowledge in a few minutes to a new set of men on each survey to have them measure and mark properly. (6) He must be able to know which trees will hold an old line and which will not, and know by a glance how old the marks are; in other words, he must be up in practical forestry and more or less a timber expert. (7) He must conform his work to that of his predecessor and perpetuate the errors of antiquity, especially if the survey he is following happens to have been made by a United States Deputy Surveyor. (8) He must be quick to decide whether it is better to cut a log across or wade a bayou or swim it, and in the latter event he must go first in order that his men may follow him. The different requisites mentioned are well known to all of us who have made land surveying our business, and we have probably all passed through the stage of attempting to set ourselves up against the old surveys on the hypothesis that 80 chains make a mile and that 6 degrees and 15 min. equal 6 degrees and 15 min., and not 7 degrees and 45 min., and have had to do our work over again for our pains.

The peculiar difficulties surrounding the greater part of Louisiana lands are due to the fact that under the old French and Spanish grants the land lines were run normal to the water courses and extended into the swamps about 1.5 miles; or, expressed as they mostly were, "so many arpents front by the depth belonging thereunto," meaning 40 arpents, or 116 chains and 36 links. These tracts have lines fitting every point of the compass, being wider on the back than in front in the bends, and closing to a common corner at the 40 arpents' line in points. There are as many as 140 tracts of land in some of our river parishes having a common corner at the back.

The descriptions of land surveys as given refer to tracts that were confirmed to the original owners in 1815, with an additional concession of 40 arpents given in continuation of the bearing of the front concession. The balance of the land was then divided into regular sections of 640 acres, numbered from 1 to 36, and from left to right, and the old grants shown by enumeration above 36, there often being more than 100 sections in one township of 6 miles square. There is also an old United States law ordering all lands on our navigable streams to be divided into lots of 160 acres by 40 acres deep, each measuring 4 acres front by 40 acres deep, side lines normal to the river bank. There are 3 770 miles of navigable streams in Louisiana, so the extent of these surveys may be readily imagined, the back and meander corner being established and the line of every fourth lot run.

The first surveyors in Louisiana were officers in the Spanish and French navy, such men as L'Hermit, Le Sage, De la Tour and others, and their work was very creditable indeed, except that, having no system of connected survey, each tract was on an entirely independent basis, and their work would answer as well for a tract of land in South Africa or China as in Louisiana. The variation of the needle used by them is seldom stated, and the clerk or recorder of conveyances has faithfully maintained this absolute disregard for location ever since. For instance, we boast of records dating back to the old Spanish owners: say McGill Torras owned four or five tracts of land in one parish, all of which he sells at various times. The deed describes thus: "Deed of McGill Torras to Carter Hood: a certain tract of land situated . . . lying and being in the Parish of . . . at about 10 miles from the Courthouse and containing 600 acres more or less," township, section and range not given. So would probably be described each tract, and after the labor of more than a week you will find that his land must be identified by the marks on the ground, after his attorney had advised him that he had an unimpeachable title. What can you do under such conditions but look wise and say little until you have finally worked out the problem in spite of his title?

Speaking of the variation of the needle, have you ever visited the surveyor-general's office and admired the system with which this has been observed? If you have not, then go there and study. In the right-hand corner of his map you will find some such legend as this: Peter Walker located the north boundary in the fourth quarter of 1829 at a variation of 7 degrees 30 sec. east. The interior sections 1 to 12 and western boundary were

surveyed by Daniel Clark in the second quarter of 1830, with a variation of 8 degrees 45 min. east; the eastern boundary and the remaining sections by A. G. Phelps in the fourth quarter of 1831, with a variation of 9 degrees east. Take your compass and close the survey if you can, or plat your work. You will find incongruities that cannot be reconciled. When this work was done on the part of our government just a few years after the cession of this country, the pioneers wrought more with sword and axe than with the sciences, but they were rigidly honest and dared hardships unknown to us. Many times I have traced their lines through trackless forests and wondered how they could have braved the dangers of Indians, mosquitoes and varmints and faithfully executed their duty, especially through the alluvial lands subject to annual inundation. They were generally accompanied by a small party, and it was nothing uncommon for them to divide their provisions and outfit, — coffee, sugar, meat, bread and potatoes and a few cooking utensils,— the surveyor himself carrying strung across his shoulders a side of bacon, their resting place for the night being the shelter of a tree. This was told me by an old citizen who had been in his early youth one of the chainmen of A. S. &. A. G. Phelps (1830).

The general honesty must not be construed to mean that all of our lands were honestly surveyed, as we had in the western part of the state a large number of townships which were surveyed in the office of the surveyor where water courses and lakes, also beautiful ridges, were shown that existed only in the mind of the artist; and worst of all the surveys were accepted.

Speaking of the hardships of surveyors I can well remember in 1879, after admiring the long steps which I thought actually measured a yard, taken by the surveyor with whom I first worked, I concluded to embark upon the arduous duties of chaining. It was during the month of August and extremely hot, and mosquitoes, snakes, hornets and bumblebees were abroad in great numbers; it was the time of the year when the wasp nests were getting ripe. After looking for a considerable length of time for an old corner in the lower part of Bayou Maringouin, a desolate and uninhabited country, we at length found an old post, a charred piece of cypress about 4 in. square, facing the old bearing tree. We had gone probably about 1½ miles, or to the 40 arpent line from that bayou, when dinner time came and the party was nearly famished for water, not having carried any with it in the morning. We had sent back one of our negro laborers for water, and the whole party waited patiently

for his return. After a short time we could see the glitter of the tin bucket in the sun, about a mile distant, and then we became more thirsty and more expectant in anticipation of the drink of bayou water we were about to receive. But sad to relate, our hopes were never to be realized, for in cutting the line over a large fallen cypress we had disturbed a wasp nest, and Jack, who had climbed up to the top of the log, was attacked and came down head first and bucket down, and the total remaining contents of the bucket was about one fourth of a pint. By some accident I failed to be the first to reach the bucket, and my companion, the head chainman, reached the bucket and drained its contents to the last drop. The surveyor, who was himself very thirsty, used some very strong language on this occasion, and my friend, the head chainman, never had any use for him afterwards.

My first experience with the compass and chain in charge of actual work occurred about 1883. It happened that an old gentleman who resided in our town had entered a large tract of land on the Natalbany River, in the Free State of Livingston, and, as an act of great kindness and patronage to me, embarked me out on my first survey, with the necessary funds to pay for labor, chainmen, etc., charged with the duty of finding out whether this valuable land had been depredated upon by being tapped for turpentine. I hired a horse, slung my compass over my shoulder and rode 50 miles to the land. Some of the oldest inhabitants pointed out the corners to me and we started on a survey of 4 000 acres in the pine woods. It took me about five days to complete the job, and at night I studied Gillespie in order to be sure that I had made no errors. I could not disabuse my mind of the idea that in order to find a variation of east the variation on the vernier should be turned to the right, as it was by me; and after I had completed the survey one of my corners was about half a mile from where it should have been, and then I began to get busy and found my error, which was some 14 degrees, and I was compelled to employ the necessary labor at my own expense to correct the error and establish the lines in their true position. I hope this may never happen to any of you.

Personal quarrels between neighbors about matters of an entirely different nature have often caused a most bitter land dispute. I remember on one occasion I was sent to give notice to an old gentleman in Iberville Parish that we would be at the upper back corner of his land the next morning at eight o'clock and there proceed to establish the line. This line had been run

many times because the neighbors did not agree and were not then on speaking terms. The old gentleman read the notice and answered verbally that he would be there and bring his shotgun with him, and so he did, and throughout the survey he followed with his shotgun on his shoulder, but fortunately no one was hurt.

A great many engineers who have been during their entire lives used to the tripod cannot well conceive how a Jacob staff is a useful instrument in land surveying. They say that it cannot be kept at a perpendicular; that it leans from one side to the other, and is unsteady; but did it ever strike you what a weapon a Jacob staff is in the hands of a man who from long experience can hit a spot in the ground every time? Think what a protection it is to him from snakes and dogs! It is an instrument both of science and defense; and, strange as it may seem, through miles of lines the slight errors will correct themselves and you will get a reasonably straight line with a sight compass and Jacob staff.

There are many variations to the needle during the day. The wind blowing across the glass can so electrify it as to prevent it from revolving, but a little water applied to the glass by wetting the finger will overcome this. During the summer months especially the diurnal variation is very perceptible and no line can be perfectly straight without constantly using back sights. But I suppose it is agreed among all engineers that the running of a straight line, even with the most modern and powerful instruments, is one of the hardest propositions in engineering. It is a mere chance when a long tangent in railroad location is perfectly straight, and a subject of great pride to the engineer who has performed this feat, even though he used tacks and checked his sights from hub to hub.

I referred in speaking historically to the imagination of the ancients in regard to the powers of the magnet, but among the ignorant even to-day strange powers are attributed to the magnetic needle. I have been told by some of my help on different surveys that the needle would flutter and flutter and would not pass a pot of gold, but I have never yet been fortunate enough to find one.

Among the greatest men in the history of our nation, at least two of our Presidents have followed the humble calling of land surveyor — George Washington and Abraham Lincoln — and Jay Gould, before he became a master of finance, eked out an existence by setting 12 o'clock marks for his rural neighbors; so that however much we may be inclined to belittle the work of the compass, it has been followed by some of the nation's

greatest men. It was a potent weapon in early days to rob the poor red man of his ancestral rights; and among many of the Indian tribes the surveyor was designated as a land stealer and looked upon with awe and respect.

This paper is not, strictly speaking, a technical paper, and I hope it will be received in the same spirit in which it was written — for the entertainment of the Louisiana Engineering Society.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by July 1, 1908, for publication in a subsequent number of the JOURNAL.]

DISCUSSION OF MR. OCKERSON'S PAPER ON "DEEP WATERWAY FROM LAKES TO GULF."

(Vol. XL, Page 110, February, 1908.)

Mr. Robert Moore. — The author's statement of the "possibilities of river traffic" as compared with traffic by rail is somewhat misleading.

As a type of river traffic he takes a towboat with a fleet of barges containing 67 000 tons of coal, and as a type of traffic by rail he takes as the load per car 16.9 tons and the load per train 224.4 tons, or less than 14 carloads, these being the average car and train load of the Frisco Railroad for the past year. From these data he finds that to haul the same amount of coal as was contained on the barges would require 298 trains.

For a fair comparison, however, the conditions for the boat and for the railroad should be equally favorable. A boat with the current in its favor should be compared with a train on a water grade line; and certainly the railroad should be allowed to carry its coal in coal cars, which are now built to carry from 40 to 50 tons, and, as every one knows, are almost always overloaded. But on a water grade a locomotive can easily haul trains of from 50 to 60 cars. The St. Louis, Troy & Eastern Railroad, a coal road, brings into East St. Louis trains of this size every working day. For this purpose, however, we may assume a train of 50 cars, each loaded with 45 tons. This gives a train load of 2 250 tons, or ten times the load assumed by the author; and the fleet of barges will represent only 29.8 trains instead of 298 trains as stated in the paper.

Coming next to the speed of the boat as compared with that of the car, the author finds the speed of the towboat and barges to be from 75 to 100, or say 88 miles per day, and the "speed of freight movement by rail" to be but one fourth of this amount, or 22 miles per day, basing the latter figure upon a "high authority" not named.

Now it is true that if from the reports of the Interstate Commerce Commission we take the total freight-car mileage of all the roads in the United States for one year and divide it by the total number of freight cars of all classes and then by 365 days, we shall get a quotient of between 23 and 24 miles per day. The average of the four years, 1903, 1904, 1905 and 1906 is 23.89

miles per day, or, say, 1 mile per hour. But this figure is the average movement of all cars, empty and loaded, for all the days of the year, during a large part of which time they are standing idle in shops or on sidings. Therefore, if this figure be used at all, it should be compared only with the average movement for the same time of all boats of all classes, whether they be empty or loaded, in motion or tied up at landings. But if, in our comparison, we take a moving boat, then surely we should take a moving car. And the speed, even of the slowest freight train, can hardly be taken at less than 10 miles per hour, or ten times the speed used by the author.

The facts of this example afford, however, a good illustration of the limitations as well as the possibilities of the two methods of transportation. The coal on the barges referred to was probably and normally brought from the mine to the river in cars,* and the barges can deliver it only at the water's edge, whence it must be again transferred to cars or wagons. The banks of the river are impassable barriers.

The car, on the other hand, can take the coal from the mine and can deliver it without further handling to any point, whether on river bank or mountain top, that can be reached by a railroad track, and with proper appliances can drop it at the furnace door. To this limitation of the waterway to a single channel, open usually but part of the year, and to the unlimited ability of the railroad to reach any point at any time, is due, more than to anything else, the enormous extension of the railroad which has marked the last fifty years and the relative decline during the same time of traffic by canal and river. That the future will materially change this relation between these two classes of traffic is highly improbable.

* It is true that on the upper Ohio River and its tributaries there are at present many mines on the river bank. But these mines can only reach the outer edge of the field and must before long be either exhausted or be subject to a long and expensive underground haul that will neutralize their present advantage over the more distant mines.

OBITUARIES.

Alfred Everett Nichols.

MEMBER BOSTON SOCIETY OF CIVIL ENGINEERS.

ALFRED EVERETT NICHOLS, son of Albert Franklin and Grace Eaton Nichols, was born in Lowell, Mass., September 28, 1864. Through his mother's family he traced his ancestry back to the Revolutionary period, she being a great grand-daughter of Major Zibeon Hooker, who was drum-major at the Battle of Bunker Hill. He received his education in the public schools of his native city. Soon after entering the high school he was given, during the summer vacation, a boy's position in the city engineer's office. When the fall term began he preferred, like many another boy, not to return to school. He remained in the city engineer's office for about twelve and a half years, gaining while there an experience which was of great value to him in his life work. He left the city's employ in 1893 and immediately entered his father's office in Nichols Foundry.

His father owned and managed, besides the Nichols Foundry in Lowell, a machine shop in Nashua, N. H., devoted largely to the manufacture of the Swain Turbine Water Wheel, of which he was sole owner. During a number of years Mr. Nichols was his father's associate and assistant, giving much of his time and thought to the sale and manufacture of the Swain Turbine Water Wheel. After his father retired from active business the care and responsibility devolved upon the son, who managed the business of the firm for the next ten years. Upon the death of his father in 1907, he bought from the heirs their interest in the foundry business. It was with deep regret that he felt obliged to abandon the manufacture of the Swain Turbine because of lack of sufficient capital, a business into which he had put his strongest personal interest.

The Swain water wheel is an inward and downward discharge turbine, which, under rigid tests made in 1869, gave an efficiency of 81.7 per cent. of gross power of the water at full gate; the same at seven-eighths gate, and 80.9 per cent. at three quarters gate; results, which not only were much better than those given by any other turbine, but about as good as the best results obtained to-day. This and following tests, which further em-

phasized the efficiency of this turbine, and the relatively small cost of its installment which resulted from its relatively high speed, and its economy in maintenance, led to the replacement of the Boyden and older types by the Swain Turbine. These wheels were all built with vertical shafts until about the year 1895, when the Swain Company began to install the wheels in pairs on horizontal shafts with patented central discharge draught tubes. They were also increased in capacity to double their earliest rating. The Swain wheel stands to-day as the type of turbine that contains the fundamental principles upon which all turbines are built; to it is due the greatest improvement over the Fourneyron type, and it was the model from which the Hunt, Hercules, McCormick and other modern wheels were developed. The total power of the Swain wheels in Lowell to-day is 7 000 horse-power. Mr. Nichols was much interested in the latest type of the Swain turbine and had much to do with their manufacture and erection.

He was a member of the Eliot Church, of William North Lodge of Masons, of Mt. Horeb Royal Arch Chapter and of Pilgrim Commandery Knights Templars, also of the Royal Arcanum, the New England Foundrymen's Association and of the Boston Society of Civil Engineers.

He was married, in September, 1891, to Miss Annie Goulding, of Lowell. His home life was always his main interest. He was a companion to his boy, a lover of good music, enjoyed a good book and the quiet hour at home. Throughout his difficult business experience he always had the same cheerful and pleasant manner that characterized him through life. He died July 31, 1907, after a brief illness at the seashore, where it had been his custom in the summer months to seek rest at the week's end, and to enjoy cottage life with his family and friends.

George A. Nelson,
Arthur T. Safford,
Committee.

James Dun.

Member of the Engineers' Club of St. Louis.

The late Mr. Dun was born in Chillicothe, Ohio, September 8, 1844. He graduated in the high school of that town, afterward attending a high-class private school at St. Catherines, Ontario, and later graduated from Miami University, at Oxford Ohio.

He began his railroad career as chainman in a surveying party of the Indianapolis & Cincinnati Railway, in 1866. In 1867 he became assistant engineer of the Atlantic & Pacific Railway (now the Frisco) and continued in that position until 1871, when he became assistant engineer of the Missouri Pacific, which position he held for about three years. From 1874 to 1877 he was engineer of the Union Depot in St. Louis, and upon the completion of that work entered the service of the St. Louis & San Francisco Railroad, as superintendent of bridges and buildings, and in a very short time thereafter was appointed chief engineer of that railroad, his appointment bearing the date of April, 1877. He continued in the position of chief engineer, holding for a time the position of assistant general manager in addition, until the spring of 1890, when he became chief engineer of the Atchison, Topeka & Santa Fé. In 1900 he was appointed chief engineer of the entire Santa Fé System, remaining as such until 1906, when he became their consulting engineer, holding this position at the time of his death.

Mr. Dun became a member of this Club in January, 1890, and at the time of his death was still a member. He was elected a corporate member of the American Society of Civil Engineers June 7, 1876; he was also a member of the Western Society of Engineers and other technical societies.

Your Committee has been favored with an intimate knowledge of Mr. Dun for twenty-five years. In all that time we have failed to meet one person who, knowing Mr. Dun, did not like him personally; and the better he was known, the more he was liked. His kindness, especially to the younger members of the profession, was unvarying, and nothing was too troublesome to do to oblige a friend.

His reputation as an engineer was international; it is hardly necessary to refer to his work, as the Frisco and most of the Santa Fé System are evidence, his last important work being the construction of the Belen Cut-Off in New Mexico.

The engineering profession sustains a severe loss by his death, as do his friends — that is to say, every one who knew him.

J. F. HINCKLEY,
C. D. PURDON,
Committee.

ASSOCIATION OF ENGINEERING SOCIETIES.

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THE COLLECTION AND DISPOSAL OF MUNICIPAL WASTE AND REFUSE.

BY X. H. GOODNOUGH, MEMBER OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read before the Sanitary Section, January 1, 1908.]

ONE of the problems most closely affecting the health and comfort of a community is that of the collection and proper disposal of its waste and refuse. It has been the experience of the writer in connection with his regular duties, and as a member of a commission appointed by the mayor of the city of Boston to consider plans for improving the methods of municipal waste disposal in that city and the prevention of a nuisance therefrom, to investigate questions relating to the disposal of municipal wastes in various cities.

In connection with this work much information has been collected relating to the quantity of such wastes and the methods of disposal in use, and it is the purpose of this paper to describe these methods briefly and present subsequently certain facts showing the quantity and character of the city wastes now collected in the city of Boston and elsewhere.

CLASSIFICATION OF CITY WASTES.

First in importance are the wastes from dwellings and stores classified as household wastes, which consist of (*a*) garbage; (*b*) ashes; (*c*) refuse, consisting of wood, paper, rags, bottles, tin cans, broken furniture and utensils, sweepings from floors, yards, etc. The householder is required in parts of the cities of Boston and New York and in some of the other cities to keep the gar-

bage in one receptacle, ashes in another and the combustible wastes and certain other refuse in a third. A notice distributed to householders north of Massachusetts Avenue in the city of Boston makes the following classification of household waste and refuse:

City of Boston. Refuse Disposal.

(Cards distributed to householders north of Massachusetts Avenue.

(*Reverse side.*)

Garbage.

All vegetable matter.

Sauce bottles.

Only catsup and other sauce bottles should be put into the garbage can; all other bottles into the paper barrel.

Tin cans.

Fruit, vegetable and meat cans should be put into the garbage can; other cans into paper barrel.

Ashes.

Sawdust.

Broken bottles.

Broken glass.

Broken crockery.

Floor and street sweepings.

Oyster and clam shells.

Tobacco stems.

Note. — Where there is a large quantity, as at a restaurant, they must be hauled by the owners.

Paper.

Bottles.	Old cloth.
Rags.	Pasteboard boxes.
Tin cans.	Old shoes.
Excelsior.	Leather and rubber scraps.
Straw.	Carpets.
Mattress.	Combustible refuse generally.

In most cities, however, only two separations are required, and combustible waste and refuse are included with the ashes and house dirt.

Next in importance to the household wastes are the wastes from markets which, in the city of Boston and other large cities, are not classified either as garbage or refuse and are disposed of separately.

Beside the wastes from houses, stores, shops, etc., there are still other large quantities of municipal wastes of various kinds. The disposal of dead animals and of slaughter-house refuse is usually, in Massachusetts at least, undertaken by rendering or fertilizer establishments operated by private parties, and the rendering establishments usually care for waste meats which constitute a small portion of the market wastes. The cleanings from streets and catch-basins form a very large item in municipal wastes. Earth from excavations and other wastes from building construction are a considerable item of city waste, and stable

manure is often included, though not in very large quantities in cities in this region.

The disposal of snow, though a troublesome problem, especially in the larger cities, is sometimes carried out in connection with other city refuse, but it does not affect seriously the problem of their disposal. It may be said in passing that officials having charge of the disposal of snow in the larger cities are looking somewhat longingly toward large sewers as an aid in the solution of that problem, and experiments in that line of disposal may be expected, in the seaboard cities at least, in the near future.

The collection and disposal of sewage, a very important municipal waste, is a problem quite apart from the disposal of other refuse, though the disposal of sludge from sewage settling tanks is sometimes included.

Methods of Disposal.

A brief glance at the history of methods of refuse disposal in use in this country is of interest as indicating the causes of present conditions and some of the difficulties to be met with in improving them, and for this purpose it is not necessary to study very deeply into ancient municipal records since practically all stages of this history are being reproduced to-day in the various towns and cities, from the small town just beginning to have a system of general collection of garbage to a great city such as Boston, for example, which expends more than three quarters of a million of dollars a year in the collection and disposal of its municipal refuse.*

The first class of refuse the disposal of which thrusts itself upon municipal authorities in a growing village or town — if we except the contents of vaults and cesspools, the disposal of which is another matter — is the kitchen waste or garbage, and the common method of disposal adopted in this part of the country at least is to feed it to swine. This method frequently produces a revenue — a very important consideration to municipal governments — and the method is rarely objectionable enough in small communities to lead to a demand for a change. In the city of Cambridge, for example, the revenue from the sale of garbage amounted, in the year 1907, to $10 564.07.

The general collection and disposal of ashes and refuse other than garbage is a matter which presents itself as a municipal problem at a later stage of city growth and is commonly not

* Not including street sweepings.

forced upon the attention of municipal authorities until the method of garbage disposal has become established. Moreover, ashes and other refuse do not constitute a source of income as garbage commonly does, nor are these materials of an offensive character like garbage. Consequently, they can be disposed of by dumping in out-of-the-way places, and as such areas are usually readily available in the towns and smaller cities, at comparatively short hauls, objection to this method of disposal of such wastes is not, usually, serious in the smaller communities.

As the cities and towns grow, however, very objectionable nuisances frequently result from this method of disposal of ashes, waste and refuse. For example, I may mention a city of about 20 000 inhabitants in which I was called upon to advise as to refuse disposal a few years ago. In this case the ashes and other refuse excepting garbage had been disposed of by dumping at many different places in low lands along the banks of a river which flowed through the city. The low lands gradually became filled to the edge of the water, and then portions of the dumps were washed away from time to time in freshets and deposited along the banks of the stream elsewhere. The result was to transform a naturally beautiful stream, the banks of which were used in many places as playgrounds, into a most unsightly nuisance.

In the larger cities longer hauls make the disposal of ashes and refuse by dumping increasingly expensive, but so long as this method is tolerated and the expense is not too great, its use continues.

Thus the methods of collection and disposal of the two most important classes of household wastes have been developed separately, and in this country, up to the present time, those classes of waste have continued as a rule to be disposed of by separate methods. With the increase in the size of a city the difficulty of disposing of the garbage for the feeding of swine increases, and with the growing demand for better sanitary conditions in recent years the objections to swine feeding as a method of garbage disposal have raised serious obstacles to the further continuance of that method.

It is worth while, however, to call attention in passing to a remarkable development of that method of garbage disposal which is found in the city of Worcester, where the garbage from a large part of the city is collected by the overseers of the poor, who maintain a municipal piggery from which a considerable income is derived. The importance of this income has thus far

been successfully urged when the health officials of that city have recommended the introduction of a sanitary method of garbage disposal.

When the disposal of garbage by feeding to swine becomes too objectionable for longer toleration, or becomes impracticable for other reasons, the next method presenting itself is usually to dump the material on land, or better, if practicable, at sea. The disposal of garbage by dumping on land, using it as a fertilizer or burying it in trenches, has not been practised very extensively in this region. The dumping of garbage at sea was begun by the city of Boston apparently not more than twenty years ago. In the beginning, moreover, the employment of this method was not extensive, for in the report of the Street Department for the year 1891 it is stated that only such of the offal as was decayed was dumped at sea, the amount so disposed of in that year being about 3 per cent. of the total quantity collected. The remainder was sold for the feeding of swine. The city of Lynn has recently reached the stage where a portion of the garbage is disposed of by dumping at sea, though the quantity thus far disposed of in that manner is not large. The garbage of the town of Hull, which includes the great summer resorts of Nantasket and its neighborhood, is also dumped at sea during the summer season.

When the further employment of methods of garbage disposal such as those herein referred to becomes impracticable, the next step is the introduction of some method of destruction. There are many of these methods, but they may be readily divided into two general classes, both of which apply to garbage only: one, burning or cremation; and the other, reduction. The former method seeks simply to reduce the garbage to inoffensive clinker or ashes, while the reduction method is designed to extract from the garbage materials of commercial value which will reduce the cost of disposal.

Garbage crematories have been installed in many cities in this country, but in a very large number of cases they have been reported as unsatisfactory or have later been superseded by other designs or by a different method. The crematories which I have seen in American cities are furnaces operated under ordinary draft, usually with coal as a fuel. A recent examination of a furnace of this kind used, in this case, for the burning of market wastes, showed serious defects from a sanitary point of view. The heat was not great enough to destroy the odors at all times, and the heavy gases generated in the furnace, though discharged

through a tall chimney, fell to the ground and were very offensive. The refuse was not completely burned, and the charred mass discharged from the furnace containing unburned material was offensive and much of it had to be reburned. Coal was being used, though not in large quantities, as the wastes contained much combustible material. The operation of this furnace in or near a populated district in the manner in which it was being operated when examined would be intolerable.

The reduction process is used chiefly in the larger cities and is the method employed in Boston, New York, Cleveland and elsewhere. The method is designed to recover from the garbage, while effecting its satisfactory disposal, materials of commercial value as an offset to the cost of disposal. By this method the garbage is cooked with steam for several hours in iron cylinders set vertically, each having a capacity of several tons. After cooking, the grease is drawn out, barreled and sold, the price obtained recently being apparently from three to four cents per pound. The tankage is pressed, dried and ground and sold for fertilizer. This method of garbage disposal was introduced in Boston in 1898, when a contract was made with a private company to dispose of the city garbage, under which the city pays $52 400 a year for this work. Concerning the introduction of this method the following statement is made in the report of the superintendent of streets for the year 1898:

"A more sanitary method of disposing of the city offal has long been under consideration, and as a result of investigations made by a committee appointed by the city government a contract for a term of ten years was made with the New England Sanitary Product Company in January, 1898, by the provisions of which nearly 77 per cent. of the collection is conveyed to an isolated point within the city limits and treated by a method known as the 'Improved Arnold Process,' which disposes of it n an unobjectionable manner."

In that year (1898) 59 per cent. of the garbage of the city of Boston was sold for feeding swine and the remainder dumped at sea. The new garbage plant has received and disposed of a gradually increasing portion of the offal of the city since it was put into operation in the latter part of 1898 or the early part of 1899, and it is stated that after March 4, 1899, the sale of offal to farmers entirely ceased and the dumping of offal at sea was discontinued. Apparently this refers to the offal of the downtown districts, since offal from some of the suburban districts is still sold for the feeding of swine, though the quantity so disposed of is now very small.

It is interesting to note that, notwithstanding the expectation of the department as quoted above, a serious nuisance resulted at the first location of the reduction plant,— at Calf Pasture in Dorchester,— and the location was subsequently changed to Spectacle Island in Boston Harbor. Even here complaints of objectionable odors from these works have appeared in the newspapers from time to time. The contract with the garbage disposal company runs until 1912.

One other city in Massachusetts (New Bedford) employs this method of garbage disposal. The process used in that city is somewhat different, though the products are similar. The works are located in a sparsely settled region two or three miles from the city proper.

The disposal of garbage has not been made as yet commercially profitable, at least to the cities in which it is used. The works are, in nearly all cases, owned by private companies subsidized by the city, and no definite information is available as to the cost of construction or maintenance, or the income obtained. It is evident, however, that the best economy with such plants is attained where they are operated in large units, and the use of this method of garbage disposal usually involves long hauls in order that all of the material may be disposed of at a single plant. About four years ago the city of Cleveland purchased the garbage reduction plant of that city and has greatly enlarged and improved it, so that it will soon be practicable to learn something of the economy of this method of garbage disposal in a large city. It should be added, however, that the Cleveland plant is situated in an isolated locality, where objections on sanitary grounds are not likely to be raised.

Like cremation plants, plants for reduction of garbage as thus far developed have been objectionable on account of offensive odors therefrom, and the waste water from such establishments contains much offensive organic matter and is likely to create a nuisance unless provision is made for its satisfactory disposal.

It is evident that if these plants are to continue in use in some of the places in which they have been installed, more efficient provision for the prevention of nuisance will have to be made.

Referring again to the disposal of ashes and other household wastes and refuse, we have seen that the usual method is to dump them upon the most convenient area of land available for the purpose. In the smaller cities this method of disposal is generally

the least expensive one available, but in larger cities longer hauls to available dumping places increase the cost, and the length of haul is, as a rule, a constantly increasing one. In the densely populated parts of the city of Boston, for example, cartage to dumps on land long ago became very expensive, and for many years much of the waste and refuse in the downtown districts of the city has been dumped at sea. The fouling of the shores of the bay resulting from this practice led to a change in the dumping place by carrying the material farther to sea, and subsequently to the installation of the garbage plant to which reference has already been made. It was still found necessary, however, to remove from the mass of refuse dumped at sea a larger proportion of the material likely to float, and the plan finally selected for accomplishing this result was to require the householder in the districts from which the refuse is disposed of at sea to keep combustible waste separate from other materials and to burn the combustible waste so that the ashes only would require disposal.

For burning the combustible waste an incinerator plant was erected in 1899 and is in operation at the present time. This plant, like the garbage plant, is owned by a private company subsidized by the city and operated under a contract which in this case will terminate in 1908. Under this contract the city delivers to the plant the combustible wastes and refuse from certain districts free from garbage and certain other objectionable matters and pays the incinerator company the sum of $5 500 per year. The city also pays all taxes, rent of land, water rates, etc. The waste is picked over for salable material, sorted out, and the remainder burned. The ashes and incombustible matters are deposited in the city dumping scows and dumped at sea. As in the case of the garbage plant, information as to the cost of operation and economies resulting therefrom is lacking, but there is no reason to doubt that the income from the sale of merchantable material is a very considerable one. Plants similar to this are in operation in the city of New York, and the method is to be tried in other cities.

These furnaces are adapted only to the burning of paper, wood and light combustible wastes generally, and are not, or at least if properly designed and maintained, need not, be objectionable if located in populous districts. An attempt has been made in some cases to utilize the heat from such plants for making steam, and a small amount of power has been secured in this way at several of the plants. The power produced does not, however, constitute a considerable economy in any case.

Natural draft is used, the heat attained is not great and it is very doubtful whether the power obtainable can be made to produce a considerable income from the operation of such plants.

Clean ashes unmixed with other wastes may be dumped upon land and used for filling or dumped into the sea without serious objection from a sanitary point of view. The object of the third separation, so called, is to keep separate from the ashes and other wastes those materials which would be objectionable or unsightly if deposited upon inland dumps, or which might float ashore if dumped at sea; but the separation of combustible materials from the ashes and other wastes in the cities in which it is enforced does not extend to all parts of the city, nor is the separation thorough in the districts in which it is enforced.

In the city of New York, as already stated, a part of the combustible waste is disposed of by burning in incinerator plants. Most of the remainder is now disposed of upon dumps near the shores of the harbor remote from the city, and little or none is now dumped into the sea. At many of the shipping points for city waste the combustible material is baled and when deposited upon the dumps does not create objection in the neighborhood, but this is a costly and troublesome method for the disposal of such wastes.

In the city of Boston, even in the districts in which the third separation is enforced, a great amount of combustible waste is still discharged, either upon the dumps, to be blown about the neighborhood, or into the sea, to float to neighboring shores. Observations of the results of the third separation now provided for in the part of the city north of Massachusetts Avenue show that the result at present is a very unsatisfactory one. Observations of the number and character of the loads of material classed as ashes have been made at Fort Hill Wharf — the principal shipping point of such wastes in the city of Boston — during the past year, which will probably give a fair indication of the efficiency of the third separation. Observations made on June 10, 1907, show that out of 177 loads of ashes and house dirt dumped into the scows at that wharf on that date, only 20 loads, or 11 per cent., consisted wholly of ashes. The remainder was made up in varying proportions — sometimes wholly — of paper and other refuse. A similar study on June 22, 1907, showed that out of 194 loads, 14, or a little over 7 per cent., were composed wholly of ashes, while of the remainder, 113, or 63 per cent., were more than half paper and

other refuse. Further observations made on December 9 showed that, out of 393 loads, 118, or 30 per cent., were all ashes, while another 30 per cent. was more than half paper and combustible waste.

These facts show that the third separation, as it is called, has not thus far been thorough in the districts in which it has been tried, and it is evident that it will be extremely difficult of general enforcement, if not impracticable. A similar condition exists in the city of New York.

There is no doubt that the introduction of the incinerator plant and the separation of a part of the combustible materials from the other wastes in parts of the city of Boston have diminished the nuisance resulting from the dumping of city wastes at sea, but the aggregate quantity of combustible waste and refuse still disposed of by dumping at sea or upon land is constantly increasing and must continue to increase in the future, as the city grows, and become objectionable, unless further provision is made for its satisfactory disposal.

So far as the disposal of market wastes is concerned, where any other method has been provided than dumping, the method employed has been either to include them with the garbage, where they would seem properly to belong, or to provide for their separate disposal by burning.

This brief review of the present methods of refuse disposal and the conditions resulting therefrom indicates that at the present time the tendency in American cities is to separate household wastes into three distinct classes: (1) garbage, (2) ashes, and (3) combustible waste and refuse; and to dispose of these different classes of waste by separate and distinct methods, — the garbage by burning in furnaces constructed for the purpose or by reduction for the recovery of salable by-products; the ashes and house and store dirt by dumping in available places on land or at sea; and the combustible wastes by incineration in simple furnaces designed for that purpose, with the recovery of certain materials picked from the waste and an attempt to secure power by utilizing the heat produced.

Combustible wastes have not thus far, however, been separated efficiently from the ashes and the difficulty of enforcing complete separation is regarded in some places as insuperable. It is important to note in this connection that in one city where there is no third separation a furnace is being erected for the burning of the ashes and combustible waste without any attempt at separation. This plan, if successful, promises a

change in method and may indicate that the attempt at a third separation will not be carried to a greater development than it has thus far reached. There are other indications also that the value of the third separation may not be sufficient to warrant its further development.

Taken as a whole, the methods of garbage and refuse disposal in American cities are inefficient and unsatisfactory, and many cities are investigating the subject, and new methods are being tried. Unfortunately for the satisfactory solution of these problems they are still commonly referred for investigation to committees of city governments, made up usually of men who lack the necessary training and experience to collect the necessary facts and study the problems intelligently, and many failures and much waste of money are the necessary results. The disposal of city waste and refuse is an engineering problem, and until they are treated as such satisfactory progress in their solution is unlikely.

If we now turn to the methods of refuse disposal employed in other countries, and especially in the British Isles, whose people and problems in municipal sanitation are so like our own, we find a very different condition. The English cities appear to have to some extent traversed the road over which American cities are now passing in respect of the disposal of municipal waste; but there has been a very great change in methods in recent years. The modern method of disposal of household wastes in English cities is, in brief, to collect all of those wastes — garbage, ashes, house dirt and combustible materials — in a single receptacle and to dispose of them by cremation.

The essential difference between the English cremation plants and the garbage furnaces and incinerators in use in this country is the employment in the English plants of forced draft and the attainment of temperatures in the furnaces of from 1500 degrees to 2000 degrees fahr., and even higher. The general result of the operation of these plants appears to be that they are efficient and satisfactory from a sanitary point of view and not seriously burdensome in cost of construction and operation.

Only one of these plants has thus far been erected in this region, and a brief description of it may be of interest as showing one of the types most commonly and successfully used for the destruction of municipal wastes and refuse in England.

This plant is located at Westmount, a suburb of the city of Montreal, having a population of about 12 000, bearing much the same relation to the city of Montreal that the town of Brook-

line does to the city of Boston. This destructor is a furnace containing three grates, each 5 ft. square, in a single chamber. The refuse is fed to this furnace at the top, and each grate is charged from a separate feed-hole. Steam jet blowers force air drawn from the building under the grates. From the cells the smoke and gases pass to a combustion chamber, so-called, to effect their thorough combustion, and the hot air passes from the combustion chamber to a boiler and thence to the chimney. On the way to the chimney the heat of the gases is reduced by heating the air used by the blowers.

This plant is said to handle about 30 tons of mixed refuse — garbage, ashes, etc. — per day and is capable of handling a somewhat larger quantity. The material is reduced to ashes and clinker, the volume of which is about 30 per cent. of that supplied to the furnace. The clinker and ashes are used in part for filling for sidewalks and the material not used is dumped not far from the destructor. No fuel other than that contained in the refuse is necessary in this destructor, except for starting fires in the beginning, since the three grates are side by side, and when one is charged coals from an adjacent grate are used for the purpose. The degree of heat attained in this furnace is said to be at times from 2700 degrees to 2800 degrees. The steam generated in the boiler is used in furnishing power for an electric lighting plant adjacent to the destructor.

While this is the only destructor of the type in use in this part of the country, it should be noted here that at Staten Island a destructor of this class is now being built for the cremation of refuse in the Borough of Richmond, which is described by Mr. J. T. Fetherston, superintendent of streets, and an engineer, in a paper recently presented to the American Society of Civil Engineers.

The Montreal destructor was constructed by Meldrum, of Manchester, and the one at Staten Island is being built by Heenan & Froude. As I have already stated, while these destructors vary radically from those hitherto in use in the United States, chiefly on account of the very much higher temperatures maintained, there are very considerable differences between the different types which I will not undertake to discuss here.

Very considerable economies are claimed in the use of the English destructors, the principal one being heat, which is used for power. The English refuse apparently has a value of at least 10 per cent. of that of coal and possibly a materially higher value. The clinker resulting from cremation also appears to

have a value in some places for use in making concrete, from which sidewalks and similar structures and even buildings are made. The power developed at many of the plants in England is used for the pumping of sewage or of water or for generating electricity for lighting and other purposes.

There has been a great amount of discussion as to whether the English destructors would be found practicable in this country, and it has been urged that the character of our refuse is very different from that of English cities, and analyses have been adduced to show this difference.

Representative samples of such materials as compose city waste and refuse are exceedingly difficult to collect, and comparative analyses by different collectors and analysts may be very misleading. While it is maintained by some that there is a very considerable difference between the character of the wastes of the English cities and that of our own, others experienced in such matters have been unable to see that such material difference exists.

The only satisfactory way in which the question of the practicability of the use of the English destructors for the disposal of municipal wastes in this country will be satisfactorily determined will be by actual trials, and the results of the operation of the plants at Montreal and in the Borough of Richmond will be of great value in the information they give as to the efficiency and cost of operation of such works.

It has been for many years and is still urged by those not too familiar with questions of sewage disposal that sewage contains material of great potential value as a fertilizer and that by discharging it into rivers or the sea, or disposing of it by methods designed simply to prevent a nuisance, very valuable material is being wasted. That there is material of potential value as a fertilizer in sewage no one would deny, but hitherto no one has succeeded in devising a plan which will dispose of sewage satisfactorily and obtain any material income therefrom. A considerable quantity of apparently good fertilizing material is separated from sewage by processes of sedimentation at our various sewage disposal works, but it is rarely possible to sell this material for any price and sometimes impossible to give it away.

Municipal waste also, and doubtless to a considerably greater degree than sewage, contains materials of commercial value, and there is no doubt that a very considerable income could be made by any large city by letting out the privilege of

picking over this waste. This has been done in some of our cities. In the case of garbage, especially, is it urged that commercially valuable products in large quantity can be derived from its reduction or distillation; but it does not appear that the materials recovered have thus far been of sufficient value to make the handling of the garbage of a city commercially valuable unless the city pays for the work.

In refuse disposal, as in sewage disposal, the solving of the sanitary problem comes first, and it is essential that a method be selected which will not produce a nuisance. If this condition shall be fulfilled, any economies resulting from the method used will be a gain.

Methods of Collection and Disposal of Refuse in the City of Boston.

The collection and disposal of municipal refuse in the city of Boston is carried out by the Sanitary Department.

The city is divided into ten districts, the boundaries of which follow in part the natural topographic divisions and in part the original boundaries of former municipalities which have been annexed to the city at various times. These districts and the population of each are as follows:

		Population.	
District No. 1 . . .	South Boston . . .	71 000	
District No. 2 . . .	East Boston	51 000	
District No. 3 . . .	Charlestown	40 000	
District No. 4 . . .	Brighton	22 000	
District No. 5 . . .	West Roxbury . . .	37 000	
District No. 6 . . .	Dorchester	89 000	
District No. 7 . . .	Roxbury	109 000	
District No. 8 . . .	South End	103 000	
District No. 9 . . .	Back Bay		
District No. 10 . . .	North and West Ends	73 000	
Total		505 000	
Population, census of 1905			595 380

Classification of Municipal Waste in the City of Boston.

In the city of Boston the principal municipal wastes requiring disposal fall into six general classes:

1. Ashes, including house and store dirt.
2. House offal.
3. Combustible waste and rubbish.
4. Market refuse.
5. Street cleanings.
6. Cesspool and catch-basin cleanings.

With the exception of No. 3, the above divisions apply to all parts of the city. The third item, combustible waste and refuse, is known as the third separation and represents an attempt to keep separate from the other wastes materials which if dumped into the harbor are likely to float ashore. It applies to that portion of the city lying north of Massachusetts Avenue, but does not include Charlestown and East Boston.

Collection of Wastes.

House Dirt and Ashes. — At the present time 213 single and 20 double carts are used for collecting house dirt and ashes in all parts of the city. All of the carts are of wood, are fitted with canvas covers and so constructed that their contents can be readily dumped. This class of material is collected by the employees of the Sanitary Department except in the districts of Dorchester and West Roxbury. In Dorchester all this work is done by contractors, while in West Roxbury less than one third of the total quantity of ashes is collected by contractors.

House Offal. — About 138 carts are used for collecting house offal throughout the city. Fifty-seven are iron — 40 of which have a capacity of about 50 cu. ft. each, while 17 have a capacity of about 80 cu. ft. each. Of the 81 wooden carts in use, 7 are large carts, having a capacity of about 80 cu. ft. and the remainder are small ones, having a capacity of 40 cu. ft. All of the carts, with the exception of those last mentioned — the small wooden ones — are covered with wooden or canvas covers so arranged that the carts can be readily dumped. The small wooden carts are emptied by shoveling out the offal.

Waste and Rubbish. — The collection of this class of refuse is done entirely by employees of the Sanitary Department, most of the material collected being delivered at an incinerator plant on Hecht Wharf near Atlantic Avenue. There are 56 carts used in this work. Thirty-four of these have a capacity of 109 cu. ft. each, while the remainder will hold double this amount. All the carts are of wood and are fitted with canvas covers. They are not so arranged that they can be dumped. The material has to be removed by hand through doors in the rear of the carts.

Street Cleanings. — Street cleanings are collected by the Street Department, which uses 104 carts in this work. They have a capacity of about 50 cu. ft. each, are made of wood and are not covered, Sixty-eight of the carts are owned by the city and the remainder are hired. Part of the work — that in

Brighton and West Roxbury — is in charge of the Street Paving Department.

Cesspool and Catch-Basin Cleanings. — Cesspool and catch-basin cleanings are collected by the Sewer Department, and during the year 1906, 42 carts — 22 single and 20 double — were in use at one time or another on this work. Of the single teams, 16 belong to the city and 6 were hired from contractors, while of the double teams, 1 is owned by the city and 19 by contractors. The double teams are all of wood and fitted with wooden covers, but a part of the single teams owned by the city are made of steel in the form of a half cylinder, fitted with covers so arranged that the material can be easily dumped. The half-cylinder carts have a capacity of about 30 cu. ft., while the larger wooden carts hold 35 cu. ft.

Frequency of Collection.

House dirt and ashes are collected either once or twice a week during the winter time and only once a week in summer. Paper and rubbish are collected chiefly on Mondays and Thursdays, in the portion of the city north of Dover Street, and on Wednesdays and Saturdays in the remaining districts. In the districts of the city where there is no third separation, such material is mixed with the ashes.

House offal is removed from dwelling houses, as a rule, once a week in the winter and twice a week in summer, except in the Back Bay, where it is removed twice a week throughout the entire year, while in the business portion of the city — Districts 8, 9 and 10 — the large hotels and restaurants are visited daily.

Quantity of Waste and Refuse of Various Kinds Collected in the City of Boston.

A careful record is kept by the Sanitary Department of the total number of loads of materials of various kinds collected and disposed of throughout the city on each day in the year, and from these records as a basis an estimate has been prepared of the total volume and weight of refuse of various kinds collected in the city in the year 1906. As a basis for estimating the volume and weight of the various materials, numerous carts of various capacities and of different materials have been measured and weighed in different months of the past year. With these results, and the records of the Sanitary Department as a basis, the following table has been prepared:

TABLE No. 1. — BOSTON REFUSE DISPOSAL.

TABLE SHOWING AVERAGE WEEKLY AND DAILY QUANTITIES (CU. FT. AND TONS) OF REFUSE COLLECTED FROM THE **Entire City** DURING EACH MONTH OF THE YEAR, MAY, 1906, TO APRIL, 1907. (Population, 1905, 595 380.)

Month		Cubic Feet. Average Weekly.	Cubic Feet. Average Daily.*	Tons. Average Weekly.	Tons. Average Daily.*	Month		Cubic Feet. Average Weekly.	Cubic Feet. Average Daily.*	Tons. Average Weekly.	Tons. Average Daily.*
January	Ashes	431 800	78 510	10 797	1 963	July	Ashes	252 400	45 892	6 311	1 148
	Rubbish	62 843	11 426	247	45		Rubbish	54 728	9 950	215	39
	Garbage	67 550	12 282	1 437	261		Garbage	57 300	10 418	1 220	222
	Market refuse	6 030	1 096	128	23		Market refuse	2 410	438	52	9
	Total	568 223	103 314	12 609	2 292		Total	366 838	66 698	7 798	1 418
February	Ashes	446 250	81 137	11 156	2 028	August	Ashes	263 700	47 946	6 592	1 198
	Rubbish	58 838	10 698	231	42		Rubbish	57 247	10 408	225	41
	Garbage	65 300	11 873	1 391	253		Garbage	62 850	11 428	1 340	244
	Market refuse	6 360	1 156	136	25		Market refuse	6 980	1 268	149	27
	Total	576 748	104 864	12 914	2 348		Total	390 777	71 050	8 306	1 510
March	Ashes	439 300	79 872	10 983	1 997	September	Ashes	258 900	47 072	6 474	1 177
	Rubbish	61 710	11 222	243	44		Rubbish	56 833	10 334	224	41
	Garbage	64 750	11 772	1 378	250		Garbage	61 900	11 254	1 319	239
	Market refuse	7 050	1 282	150	28		Market refuse	7 920	1 440	169	30
	Total	572 816	104 148	12 754	2 319		Total	385 553	70 100	8 186	1 487
April	Ashes	416 250	75 682	10 406	1 892	October	Ashes	295 850	53 792	7 396	1 344
	Rubbish	62 784	11 415	247	45		Rubbish	62 130	11 296	244	44
	Garbage	61 250	11 136	1 305	237		Garbage	66 400	12 072	1 414	257
	Market refuse	6 430	1 169	137	25		Market refuse	6 780	1 232	144	26
	Total	546 714	99 402	12 095	2 199		Total	431 160	78 392	9 198	1 671
May	Ashes	366 500	66 636	9 162	1 666	November	Ashes	325 150	59 118	8 130	1 478
	Rubbish	60 212	10 948	237	43		Rubbish	60 146	10 936	236	43
	Garbage	60 700	11 036	1 294	235		Garbage	62 100	11 290	1 323	240
	Market refuse	7 250	1 318	154	28		Market refuse	6 160	1 120	132	24
	Total	494 662	89 938	10 847	1 972		Total	453 556	82 464	9 821	1 785
June	Ashes	279 900	50 890	6 999	1 272	December	Ashes	397 850	72 336	9 947	1 809
	Rubbish	59 873	10 886	236	43		Rubbish	61 422	11 168	241	44
	Garbage	61 400	11 164	1 309	238		Garbage	66 650	12 118	1 421	258
	Market refuse	7 180	1 306	153	28		Market refuse	5 960	1 084	127	23
	Total	408 353	74 246	8 697	1 581		Total	531 882	96 706	11 736	2 134
						Average	Ashes	347 820	63 240	8 696	1 581
							Rubbish	59 899	10 891	235	43
							Garbage	63 179	11 487	1 346	244
							Market refuse	6 375	1 159	136	25
							Total	477 273	86 777	10 413	1 893

* $5\frac{1}{2}$ days per week.

1 cu. yd. ashes = 1 350 lb.
1 ,, rubbish = 212 ,,
1 ,, garbage = 1 150 ,,
1 ,, market refuse = 1 150 ,,

The total quantity for any month can be obtained approximately by multiplying the average daily quantity, as given above, by 24.

In the next table are given the monthly variations in the amounts of the principal classes of refuse collected in the entire city during the year ending April 18, 1907. This table shows that the quantity of ashes, for example, collected in January and February is a little less than twice the quantity collected in the warmer summer months. The house offal apparently varies little in quantity from month to month.

Quantity of Refuse Collected in Certain Districts in the City of Boston.

As already stated, the Sanitary Department has found it convenient to divide the city into districts, following in part topographical lines and in part the lines of former municipalities annexed to the city many years ago. It has been practicable from the records of the department to determine the quantity of waste and refuse of various kinds collected in each district, and the result is of much interest in connection with the problem of waste disposal.

The different districts into which the city is divided vary greatly in character. South Boston, East Boston and Charlestown are for the most part closely built up and are densely populated. In each of those districts, and especially in East Boston, there is a large extent of water front used for shipping and for general commercial purposes, and a considerable amount of manufacturing is carried on in all these districts. The North and West Ends are very densely populated, largely by foreigners of various nationalities. The district includes much of the business portion of the city, the principal wharves and markets and many hotels. The South End is mainly a densely populated residential district. The Back Bay includes numerous hotels and the best class of dwelling houses in the city. Roxbury is in part residential, but contains in its lower portions many factories and a dense population. Brighton, Dorchester and a large part of West Roxbury are suburban in character, comparatively sparsely populated and have little or no manufacturing within their limits.

In the following tables are given the average weekly quantities of waste of various kinds collected in each of the districts of the city in the year 1906, together with the percentage or ratio of each class of waste to the total quantity of wastes. The total for each month is not kept in the records of the Street Department, but can be obtained approximately from these tables by multiplying the average weekly quantity as given by 4.3.

TABLE No. 2. — BOSTON REFUSE DISPOSAL. Showing Average Weekly Quantities (Cu. Ft. and Tons) of Refuse Collected from **Entire City** during Each Month of the Year, May, 1906, to April, 1907. (Population, 1905, 595 380.)

		Cubic Feet.		Tons.				Cubic Feet.		Tons.		
		Average Weekly.	Per Cent.	Average Weekly.	Lb.* per Capita per Day.	Per Cent.		Average Weekly.	Per Cent.	Average Weekly.	Lb.* per Capita per Day.	Per Cent.
January	Ashes	431 800	75.9	10 797	6.60	85.6	July	252 400	68.8	6 311	3.86	81.0
	Rubbish	62 843	11.1	247	.45	2.0		54 728	14.9	215	.13	2.8
	Garbage	67 550	11.9	1 437	.88	11.4		57 300	15.6	1 220	.75	15.6
	Market refuse	6 030	1.1	128	.08	1.0		2 410	.7	52	.03	.6
	Total	508 223	100.0	12 609	7.71	100.0		366 838	100.0	7 798	4.77	100.0
February	Ashes	446 250	77.4	11 156	6.81	86.3	August	263 700	67.5	6 592	4.02	79.4
	Rubbish	58 838	10.2	231	.14	1.8		57 247	14.6	225	.14	2.7
	Garbage	65 300	11.3	1 391	.85	10.8		62 850	16.1	1 340	.82	16.1
	Market refuse	6 360	1.1	136	.08	1.1		6 980	1.8	149	.09	1.8
	Total	576 748	100.0	12 914	7.88	100.0		390 777	100.0	8 306	5.07	100.0
March	Ashes	439 300	76.7	10 983	6.71	86.1	September	258 900	67.2	6 474	3.95	79.0
	Rubbish	61 716	10.8	243	.15	1.9		56 833	14.7	224	.14	2.8
	Garbage	64 750	11.3	1 378	.84	10.8		61 900	16.1	1 319	.81	16.2
	Market refuse	7 050	1.2	150	.09	1.2		7 920	2.0	169	.10	2.0
	Total	572 816	100.0	12 754	7.79	100.0		385 553	100.0	8 186	5.00	100.0
April	Ashes	416 250	76.1	10 406	6.36	86.1	October	295 850	68.6	7 396	4.51	80.3
	Rubbish	62 784	11.5	247	.15	2.0		62 130	14.4	244	.15	2.7
	Garbage	61 250	11.2	1 305	.80	10.8		66 400	15.4	1 414	.86	15.4
	Market refuse	6 430	1.2	137	.08	1.1		6 780	1.6	144	.09	1.6
	Total	546 714	100.0	12 095	7.39	100.0		431 160	100.0	9 198	5.61	100.0
May	Ashes	366 500	74.1	9 162	5.60	84.5	November	325 150	71.6	8 130	4.98	82.8
	Rubbish	60 212	12.2	237	.15	2.2		60 146	13.3	237	.15	2.4
	Garbage	60 700	12.3	1 294	.79	11.9		62 100	13.7	1 323	.81	13.5
	Market refuse	7 250	1.4	154	.09	1.4		6 160	1.4	132	.08	1.3
	Total	494 662	100.0	10 847	6.63	100.0		453 556	100.0	9 822	6.02	100.0
June	Ashes	279 900	68.6	6 999	4.28	80.4	December	397 850	74.8	9 947	6.07	84.7
	Rubbish	59 873	14.7	236	.15	2.7		61 422	11.5	241	.15	2.1
	Garbage	61 400	15.0	1 309	.80	15.1		66 650	12.5	1 421	.87	12.1
	Market refuse	7 180	1.7	153	.09	1.8		5 960	1.2	127	.08	1.1
	Total	408 353	100.0	8 697	5.32	100.0		531 882	100.0	11 736	7.17	100.0
Average	Ashes							347 821	72.3	8 696	5.31	83.0
	Rubbish							59 898	12.8	236	.15	2.3
	Garbage							63 179	13.5	1 346	.82	13.3
	Market refuse							6 376	1.4	136	.08	1.4
	Total							477 274	100.0	10 414	6.36	100.0

* 5½ days per week. 1 cu. yd. ashes = 1 350 lb. 1 cu. yd. garbage = 1 150 lb. 1 cu. yd. rubbish = 212 lb. 1 cu. yd. market refuse = 1 150 lb.

TABLE No. 3. — BOSTON REFUSE DISPOSAL. SHOWING AVERAGE WEEKLY QUANTITIES (CU. FT. AND TONS) OF REFUSE COLLECTED FROM **South Boston** (DISTRICT No. 1) DURING EACH MONTH OF THE YEAR, MAY, 1906, TO APRIL, 1907. (Population, 1905, 71 000.)

		Cubic Feet.		Tons.				Cubic Feet.		Tons.		
		Average Weekly.	Per Cent.	Average Weekly.	Lb.* per Capita per Day.	Per Cent.		Average Weekly.	Per Cent.	Average Weekly.	Lb.* per Capita per Day.	Per Cent.
January	Ashes	31 900	85.5	798	3.87	89.3	July	20 550	81.8	514	2.49	86.1
	Refuse	1 134	3.0	4	.02	.4		872	3.4	3	.01	.5
	Garbage	4 300	11.5	92	.44	10.3		3 750	14.8	80	.39	13.4
	Market refuse	0	0.0	0	0.00	0.0		0	0.0	0	0.00	0.0
	Total	37 334	100.0	894	4.33	100.0		25 172	100.0	597	2.89	100.0
February	Ashes	31 450	86.5	786	3.81	89.6	August	21 450	80.5	536	2.60	84.9
	Rubbish	654	1.8	2	.01	.2		872	3.3	3	.01	.4
	Garbage	4 200	11.7	89	.43	10.2		4 350	16.2	93	.45	14.0
	Market refuse	0	0.0	0	0.00	0.0		0	0.0	0	0.00	0.7
	Total	36 304	100.0	877	4.25	100.0		26 672	100.0	632	3.06	100.0
March	Ashes	32 050	86.5	801	3.88	89.9	September	19 700	79.3	493	2.39	83.9
	Rubbish	872	2.4	3	.01	.3		872	3.4	3	.01	.5
	Garbage	4 100	11.1	87	.42	9.8		4 350	17.3	93	.45	15.6
	Market refuse	0	0.0	0	0.00	0.0		0	0.0	0	0.00	0.0
	Total	37 022	100.0	891	4.31	100.0		24 922	100.0	589	2.85	100.0
April	Ashes	28 200	85.8	705	3.42	89.6	October	22 300	81.4	558	2.71	85.7
	Rubbish	926	2.8	4	.01	.4		872	3.2	3	.01	.4
	Garbage	3 700	11.4	79	.38	10.0		4 250	15.4	91	.49	13.9
	Market refuse	0	0.0	0	0.00	0.0		0	0.0	0	0.00	0.0
	Total	32 826	100.0	788	3.81	100.0		27 422	100.0	652	3.21	100.0
May	Ashes	28 000	82.9	700	3.39	89.2	November	20 450	81.2	511	2.48	85.7
	Rubbish	2 224	6.6	8	.04	1.2		872	3.4	3	.01	.5
	Garbage	3 550	10.5	76	.37	9.6		3 900	15.4	83	.40	13.8
	Market refuse	0	0.0	0	0.00	0.0		0	0.0	0	0.00	0.0
	Total	33 774	100.0	784	3.80	100.0		25 222	100.0	597	2.89	100.0
June	Ashes	19 200	78.8	480	2.33	84.4	December	29 250	85.0	731	3.54	88.6
	Rubbish	1 177	4.8	4	.02	.7		872	2.5	3	01	3
	Garbage	4 000	16.4	85	.41	14.9		4 300	12.5	92	.45	11.1
	Market refuse	0	0.0	0	0.00	0.0		0	0.0	0	0.00	0.70
	Total	24 377	100.0	569	2.76	100.0		34 422	100.0	826	4.00	100.0
Average	Ashes							25 375	82.9	634	3.08	87.2
	Rubbish							1 018	3.4	4	.01	.5
	Garbage							4 063	13.7	87	.42	12.3
	Market refuse							0	0.0	0	0.00	0.0
	Total							30 456	100.0	725	3.51	100.0

* 5½ days per week. 1 cu. yd. ashes = 1 350 lb. 1 cu. yd. garbage = 1 150 lb. 1 cu. yd. rubbish = 212 lb. 1 cu. yd. market refuse = 1 150 lb.

TABLE No. 4. — BOSTON REFUSE DISPOSAL. SHOWING AVERAGE WEEKLY QUANTITIES (CU. FT. AND TONS) OF REFUSE COLLECTED FROM **East Boston** (DISTRICT No. 2) DURING EACH MONTH OF THE YEAR, MAY, 1906, TO APRIL, 1907. (Population, 1905, 51 000.)

		Cubic Feet.		Tons.				Cubic Feet.		Tons.		
		Average Weekly.	Per Cent.	Average Weekly.	Lb.* per Capita per Day.	Per Cent.		Average Weekly.	Per Cent.	Average Weekly.	Lb.* per Capita per Day.	Per Cent.
January	Ashes	23 350	78.9	584	4.13	81.0	July	20 000	78.0	500	3.54	79.4
	Rubbish	......	.....	......	....	.....		....	.....	......	....	....
	Garbage	6 250	21.1	133	0.94	19.0		6 050	22.0	129	0.91	20.6
	Market refuse	0	0.0	0	0.00	0.0		0	0.0	0	0.00	0.0
	Total	29 600	100.0	717	5.07	100.0		26 050	100.0	629	4.45	100.0
February	Ashes	25 250	80.2	631	4.47	82.7	August	20 050	78.0	501	3.54	79.6
	Rubbish	......	.....	......	....	.....		....	.....	......	....	....
	Garbage	6 200	19.8	132	0.93	17.3		6 000	22.0	128	0.91	20.4
	Market refuse	0	0.0	0	0.00	0.0		0	0.0	0	0.00	0.0
	Total	31 450	100.0	763	5.40	100.0		26 050	100.0	629	4.45	100.0
March	Ashes	24 700	80.6	617	4.36	82.8	September	18 450	75.4	461	3.26	78.3
	Rubbish	......	.....	......	....	.....		....	.....	......	....	....
	Garbage	6 000	19.4	128	0.91	17.2		6 000	24.6	128	0.90	21.7
	Market refuse	0	0.0	0	0.00	0.0		0	0.0	0	0.00	0.0
	Total	30 700	100.0	745	5.27	100.0		24 450	100.0	589	4.16	100.0
April	Ashes	24 200	80.1	605	4.28	82.5	October	19 400	74.6	485	3.43	77.5
	Rubbish	......	.....	......	....	.....		....	.....	......	....	....
	Garbage	6 000	19.9	128	0.91	17.5		6 600	25.4	141	1.00	22.5
	Market refuse	0	0.0	0	0.00	0.0		0	0.0	0	0.00	0.0
	Total	30 200	100.0	733	5.19	100.0		26 000	100.0	626	4.43	100.0
May	Ashes	30 500	83.4	762	5.40	85.6	November	20 350	77.1	509	3.60	80.0
	Rubbish	......	.....	......	....	....		....	.....	......	....	.....
	Garbage	6 000	16.6	128	0.90	14.4		6 000	22.9	128	0.91	20.0
	Market refuse	0	0.0	0	0.00	0.0		0	0 0	0	0.00	0.0
	Total	36 500	100.0	890	6.30	100.0		26 350	100.0	637	4.51	100.0
June	Ashes	20 950	77.8	524	3.71	80.4	December	21 300	76.6	533	3.77	79.4
	Rubbish	......	.....	......	....	.....		....	.....	......	....	....
	Garbage	6 000	22.2	128	0.90	19.6		6 500	23.4	138	0.98	20.6
	Market refuse	0	0.0	0	0 00	0.0		0	0.0	0	0.00	0.0
	Total	26 950	100.0	652	4.61	100.0		27 800	100.0	671	4.75	100.0
Average	Ashes							22 375	78.4	559	3.95	80.8
	Rubbish							....	....	......	....	....
	Garbage							6 133	21.6	131	0.94	19.2
	Market refuse							0	0.0	0	0.00	0.0
	Total							28 508	100.0	690	4.89	100.0

* $5\frac{1}{2}$ days per week. 1 cu. yd. ashes = 1 350 lb. 1 cu. yd. garbage = 1 150 lb. 1 cu. yd. rubbish = 212 lb. 1 cu. yd. market refuse = 1 150 lb.

TABLE No. 5. — BOSTON REFUSE DISPOSAL. Showing Average Weekly Quantities (Cu. Ft. and Tons) of Refuse Collected from **Charlestown** (District No. 3) during Each Month of the Year, May, 1906, to April, 1907. (Population, 1905, 40 000.)

Month	Item	Cubic Feet. Average Weekly.	Cubic Feet. Per Cent.	Tons. Average Weekly.	Tons. Lb.* per Capita per Day.	Tons. Per Cent.	Month	Cubic Feet. Average Weekly.	Cubic Feet. Per Cent.	Tons. Average Weekly.	Tons. Lb.* per Capita per Day.	Tons. Per Cent.
January	Ashes (b)	22 800	89.7	570	5.18	91.1	July	15 450	82.3	386	3.51	87.4
	Rubbish	.....	....	.....	....	.....		872	4.7	3.5	.03	.8
	Garbage	2 650	10.3	56	.51	8.9		2 450	13.0	52	.47	11.8
	Market refuse	0	0.0	0	0.0	0.0		0	0.0	0.	0.00	0.0
	Total	25 450	100.0	626	5.70	100.0		18 772	100.0	441.5	4.01	100.0
February	Ashes (b)	20 450	89.3	511	4.65	90.8	August	15 600	81.2	390	3.54	86.3
	Rubbish	.....	....	.....	....	.....		872	4.5	3.5	.03	.7
	Garbage	2 450	10.7	52	.47	9.2		2 750	14.3	59	.54	13.0
	Market refuse	0	0.0	0	0.0	0.0		0	0.0	0.	0.00	0.0
	Total	22 900	100.0	563	5.12	100.0		19 222	100.0	452.5	4.11	100.0
March	Ashes (b)	22 550	90.4	564	5.13	91.7	September	14 750	80.9	369	3.36	86.4
	Rubbish†	......	.....	....	....	.....		872	4.8	3.5	.03	.8
	Garbage	2 400	9.6	51	0.46	8.3		2 600	14.3	55	.50	12.8
	Market refuse	0	0.0	0	0.0	0.0		0	0.0	0	0.00	0.0
	Total	24 950	100.0	615	5.59	100.0		18 222	100.0	427.5	3.89	100.0
April	Ashes (b)	22 750	89.8	569	5.17	91.3	October	15 000	82.3	375	3.41	86.7
	Rubbish	......	....	.....	....	.....		654	3.6	2.5	.02	.6
	Garbage	2 550	10.2	54	0.49	8.7		2 600	14.1	55	.50	12.7
	Market refuse	0	0.0	0	0.0	0.0		0	0.0	0.	0.00	0.0
	Total	25 300	100.0	623	5.67	100.0		18 254	100.0	432.5	3.93	100.0
May	Ashes	21 800	88.6	545	4.96	91.5	November	14 300	82.0	358	3.26	87.4
	Rubbish	523	2.2	2	.02	0.3		872	5.0	3.5	.03	.8
	Garbage	2 300	9.2	49	.45	8.2		2 300	13.0	49	.45	11.8
	Market refuse	0	0.0	0	0.0	0.0		0	0.0	0.	0.00	0.0
	Total	24 623	100.0	596	5.42	100.0		17 472	100.0	410.5	3.74	100.0
June	Ashes	17 950	85.7	449	4.08	89.0	December	20 000	85.0	500.	4.55	89.1
	Rubbish	436	2.1	1.75	.02	0.3		818	3.5	3.25	.03	.6
	Garbage	2 550	12.2	54	.49	10.7		2 700	11.5	58.	.53	10.3
	Market refuse	0	0.0	0	0.0	0.0		0	0.0	0.	0.00	0.0
	Total	20 936	100.0	504.75	4.59	100.0		23 518	100.0	561.25	5.11	100.0
Average	Ashes (b)							18 617	85.1	465.00	4.23	89.1
	Rubbish							740†	3.4	3.00	.03	0.6
	Garbage							2 525	11.5	54.00	.49	10.3
	Market refuse							0	0.0	0.00	.00	0.0
	Total							21 882	100.0	522.00	4.75	100.0

* 5½ days per week. (b) During January, February, March and April, rubbish and ashes both reported under the head of Ashes. † Average for eight months only.
1 cu. yd. ashes = 1 350 lb. 1 cu. yd. garbage = 1 150 lb. 1 cu. yd. rubbish = 212 lb. 1 cu. yd. market refuse = 1 150 lb.

TABLE No. 6.—BOSTON REFUSE DISPOSAL. Showing Average Weekly Quantities (Cu. Ft. and Tons) of Refuse Collected from **Brighton** (District No. 4) during Each Month of the Year, May, 1906, to April, 1907. (Population, 1905, 22 000).

Month		Cubic Feet. Average Weekly.	Cubic Feet. Per Cent.	Tons. Average Weekly.	Tons. Lb.* per Capita per Day.	Tons. Per Cent.
January	Ashes	16 500	87.8	413	6.89	89.4
	Rubbish	......	....	....	....	.....
	Garbage	2 300	12.2	49	.82	10.6
	Market refuse	0	0.0	0	0.00	0.0
	Total	18 800	100.0	462	7.71	100.0
February	Ashes	16 450	88.0	411	6.85	89.5
	Rubbish	......	.....	...	....	.....
	Garbage	2 250	12.0	48	.80	10.5
	Market refuse	0	0.0	0	0.00	0.0
	Total	18 700	100.0	459	7.65	100.0
March	Ashes	16 200	88.0	405	6.76	89.4
	Rubbish	......	.....	...	....	.....
	Garbage	2 250	12.0	48	.80	10.6
	Market refuse	0	0.0	0	0.00	0.0
	Total	18 450	100.0	453	7.56	100.0
April	Ashes	15 750	87.2	394	6.57	89.1
	Rubbish	......	....	...	....	....
	Garbage	2 250	12.8	48	.80	10.9
	Market refuse	0	0.0	0	0.00	0.0
	Total	18,000	100.0	442	7.37	100.0
May	Ashes	15 000	88.0	375	6.25	89.5
	Rubbish	......	....	...	....	....
	Garbage	2 050	12.0	44	.73	10.5
	Market refuse	0	0.0	0	0.00	0.0
	Total	17 050	100.0	419	6.98	100.0
June	Ashes	13 000	86.3	325	5.42	88.1
	Rubbish	......	....	...	....	....
	Garbage	2 050	13.7	44	.73	11.9
	Market refuse	0	0.0	0	0.00	0.0
	Total	15 050	100.0	369	6.15	100.0

Month		Cubic Feet. Average Weekly.	Cubic Feet. Per Cent.	Tons. Average Weekly.	Tons. Lb.* per Capita per Day.	Tons. Per Cent.
July	Ashes	13 000	86.3	325	5.42	88.6
	Rubbish	......	.....	...	....	.....
	Garbage	1 950	13.7	42	.70	11.4
	Market refuse	0	0.0	0	0.00	0.0
	Total	14 950	100.0	367	6.12	100.0
August	Ashes	13 100	86.9	328	5.47	88.7
	Rubbish	......	.....	...	....	.....
	Garbage	1 950	13.1	42	.70	11.3
	Market refuse	0	0.0	0	0.00	0.0
	Total	15 050	100.0	370	6.17	100.0
September	Ashes	12 800	86.8	320	5.33	88.3
	Rubbish	......	.....	...	....	.....
	Garbage	1 950	13.2	42	.70	11.7
	Market refuse	0	0.0	0	0.00	0.0
	Total	14 750	100.0	362	6.03	100.0
October	Ashes	13 600	87.0	340	5.67	88.5
	Rubbish	......	....	...	....	....
	Garbage	2 050	13.0	44	.73	11.5
	Market refuse	0	0.0	0	0.00	0.0
	Total	15 650	100.0	384	6.40	100.0
November	Ashes	13 400	86.9	335	5.58	88.5
	Rubbish	......	....	...	....	....
	Garbage	2 050	13.1	44	.73	11.5
	Market refuse	0	0.0	0	0.00	0.0
	Total	15 450	100.0	379	6.31	100.0
December	Ashes	15 500	88.0	388	6.47	89.5
	Rubbish	......	....	...	....	....
	Garbage	2 100	12.0	45	.75	10.5
	Market refuse	0	0.0	0	0.00	0.0
	Total	17 600	100.0	433	7.22	100.0
Average	Ashes	14 525	87.3	363	6.06	88.9
	Rubbish	......	....	...	....	....
	Garbage	2 100	12.7	45	.75	11.1
	Market refuse	0	0.0	0	0.00	0.0
	Total	16 625	100.0	408	6.81	100.0

* $5\frac{1}{2}$ days per week. 1 cu. yd. ashes = 1 350 lb. 1 cu. yd. garbage = 1 150 lb. 1 cu. yd. rubbish = 212 lb. 1 cu. yd. market refuse = 1 150 lb.

TABLE No. 7. — BOSTON REFUSE DISPOSAL. Showing Average Weekly Quantities (Cu. Ft. and Tons) of Refuse Collected from **West Roxbury** (District No. 5) during Each Month of the Year, May, 1906, to April, 1907. (Population, 1905, 37 000.)

		Cubic Feet.		Tons.				Cubic Feet.		Tons.		
		Average Weekly.	Per Cent.	Average Weekly.	Lb.* per Capita per Day.	Per Cent.		Average Weekly.	Per Cent.	Average Weekly.	Lb.* per Capita per Day.	Per Cent.
January	Ashes	27 350	86.7	684	7.46	88.6	July	13 400	80.2	335	3.65	82.6
	Rubbish	......	....	...	....	....		......	....	...	....	....
	Garbage	4 150	13.3	88	.96	11.4		3 350	19.8	71	.77	17.4
	Market refuse	0	0.0	0	0.00	0.0		0	0.0	0	0.00	0.0
	Total	31 500	100.0	772	8.42	100.0		16 750	100.0	406	4.42	100.0
February	Ashes	29 450	88.0	736	8.02	89.6	August	14 200	78.0	355	3.87	80.7
	Rubbish	......	....	...	....	....		......	....	...	....	....
	Garbage	4 000	12.0	85	.93	10.4		4 000	22.0	85	.93	19.3
	Market refuse	0	0.0	0	0.00	0.0		0	0.0	0	0.00	0.0
	Total	33 450	100.0	821	8.95	100.0		18 200	100.0	440	4.80	100.0
March	Ashes	28 750	87.0	719	7.83	88.9	September	14 900	77.8	373	4.06	80.5
	Rubbish	......	....	...	....	....		......	....	...	...	....
	Garbage	4 250	13.0	90	.98	11.1		4 250	22.2	91	.99	19.5
	Market refuse	0	0.0	0	0.00	0.0		0	0.0	0	0.00	0.0
	Total	33 000	100.0	809	8.81	100.0		19 150	100.0	464	5.05	100.0
April	Ashes	29 100	89.1	727	7.92	90.5	October	19 250	82.8	481	5.25	85.0
	Rubbish	......	....	....	....	....		......	....	...	...	...
	Garbage	3 550	10.9	76	.83	9.5		4 000	17.2	85	.93	15.0
	Market refuse	0	0.0	0	0.00	0.0		0	0.0	0	0.00	0.0
	Total	32 650	100.0	803	8.75	100.0		23 250	100.0	566	6.18	100.0
May	Ashes	26 250	87.8	656	7.15	89.3	November	20 600	84.5	515	5.61	86.4
	Rubbish	......	....	...	....	....		......	....	...	....	....
	Garbage	3 700	12.2	79	.86	10.7		3 800	15.5	81	.88	13.6
	Market refuse	0	0.0	0	0.00	0.0		0	0.0	0	0.00	0.0
	Total	29 950	100.0	735	8.01	100.0		24 400	100.0	596	6.49	100.0
June	Ashes	15 600	81.5	390	4.25	83.6	December	24 550	85.7	614	6.70	87.6
	Rubbish	......	....	...	....	....		......	....	...	....	....
	Garbage	3 550	18.5	76	.83	16.4		4 100	14.3	87	.95	12.4
	Market refuse	0	0.0	0	0.00	0.0		0	0.0	0	0.00	0.0
	Total	19 150	100.0	466	5.08	100.0		28 650	100.0	701	7.65	100.0
Average	Ashes							21 950	84.1	549	5.98	86.1
	Rubbish							......	....	...	....	....
	Garbage							3 892	15.9	83	.90	13.9
	Market refuse							0	0.0	0	0.00	0.0
	Total							25 842	100.0	632	6.88	100.0

* 5½ days per week. 1 cu. yd. ashes = 1 350 lb. 1 cu. yd. garbage = 1 150 lb. 1 cu. yd. rubbish = 212 lb. 1 cu. yd. market refuse = 1 150 lb.

TABLE No. 8. — BOSTON REFUSE DISPOSAL. SHOWING AVERAGE WEEKLY QUANTITIES (CU. FT. AND TONS) OF REFUSE COLLECTED FROM **Dorchester** (DISTRICT No. 6) DURING EACH MONTH OF THE YEAR, MAY, 1906, TO APRIL, 1907. (Population, 1905, 89 000.)

		Cubic Feet.		Tons.				Cubic Feet.		Tons.		
		Average Weekly.	Per Cent.	Average Weekly.	Lb.* per Capita per Day.	Per Cent.		Average Weekly.	Per Cent.	Average Weekly.	Lb.* per Capita per Day.	Per Cent.
January	Ashes	56 350	87.6	1 409	6.08	89.3	July	19 200	75.1	480	2.07	78.0
	Rubbish	......	....	.....	....	....		......	....	....	....	....
	Garbage	7 950	12.4	169	.73	10.7		6 350	24.9	135	.58	22.0
	Market refuse	0	0.0	0	0.00	0.0		0	0.0	0	0.00	0.0
	Total	64 300	100.0	1 578	6.81	100.0		25 550	100.0	615	2.65	100.0
February	Ashes	66 100	89.0	1 653	7.14	90.4	August	18 650	71.3	466	2.02	74.4
	Rubbish	......	....	.....	....	....		......	.....	....	....	....
	Garbage	8 200	11.0	175	.76	9.6		7 500	28.7	160	.69	25.6
	Market refuse	0	0.0	0	0.00	0.0		0	0.0	0	0.00	0.0
	Total	74 300	100.0	1 828	7.90	100.0		26 150	100.0	626	2.71	100.0
March	Ashes	60 300	88.9	1 508	6.50	90.4	September	22 850	77.2	571	2.47	79.9
	Rubbish	......	....	.....	....	....		......	....	.....	....	....
	Garbage	7 500	11.1	160	.69	9.6		6 750	22.8	144	.62	20.1
	Market refuse	0	0.0	0	0.00	0.0		0	0.0	0	0.00	0.0
	Total	67 800	100.0	1 668	7.19	100.0		29 600	100.0	715	3.09	100.0
April	Ashes	49 650	88.4	1 241	5.36	90.0	October	28 500	79.8	713	3.08	82.3
	Rubbish	......	....	.....	....	....		......	....	...	....	....
	Garbage	6 500	11.6	138	.59	10.0		7 200	20.2	153	.66	17.7
	Market refuse	0	0.0	0	0.00	0.0		0	0.0	0	0.00	0.0
	Total	56 150	100.0	1 379	5.95	100.0		35 700	100.0	866	3.74	100.0
May	Ashes	34 150	85.1	854	3.68	87.0	November	39 950	85.5	999	4.31	87.3
	Rubbish	......	....	...	....	....		......	....	...	....	....
	Garbage	6 000	14.9	128	.55	13.0		6 800	14.5	145	.63	12.7
	Market refuse	0	0.0	0	0.00	0.0		0	0.0	0	0.00	0.0
	Total	40 150	100.0	982	4.23	100.0		46 750	100.0	1 144	4.04	100.0
June	Ashes	22 400	76.8	560	2.42	79.5	December	51 800	87.1	1 295	5.58	88.8
	Rubbish	......	....	...	....	....		......	....	....	....	....
	Garbage	6 750	23.2	144	.62	20.5		7 700	12.9	164	.71	11.2
	Market refuse	0	0.0	0	0.00	0.0		0	0.0	0	0.00	0.0
	Total	29 150	100.0	704	3.04	100.0		59 500	100.0	1 459	6.29	100.0
Average	Ashes							39 158	84.6	979	4.23	86.6
	Rubbish							......	....	...	....	....
	Garbage							7 100	15.4	151	.65	13.4
	Market refuse							0	0.0	0	0.00	0.0
	Total							46 258	100.0	1 130	4.88	100.0

* $5\frac{1}{2}$ days per week. 1 cu. yd. ashes = 1 350 lb. 1 cu. yd. garbage = 1 150 lb. 1 cu. yd. rubbish = 212 lb. 1 cu. yd. market refuse = 1 150 lb.

TABLE No. 9. — BOSTON REFUSE DISPOSAL. SHOWING AVERAGE WEEKLY QUANTITIES (CU. FT. AND TONS) OF REFUSE COLLECTED FROM **Roxbury** (DISTRICT No. 7) DURING EACH MONTH OF THE YEAR, MAY, 1906, TO APRIL, 1907. (Population, 1905, 109 000.)

		Cubic Feet.		Tons.				Cubic Feet.		Tons.		
		Average Weekly.	Per Cent.	Average Weekly.	Lb.* per Capita per Day.	Per Cent.		Average Weekly.	Per Cent.	Average Weekly.	Lb.* per Capita per Day.	Per Cent.
January	Ashes	57 800	83.7	1 445	4.74	88.1	July	34 750	77.2	869	2.85	82.8
	Rubbish	2 456	3.6	10	.03	.6		2 234	4.9	9	.03	.9
	Garbage	8 750	12.7	186	.61	11.3		8 050	17.9	171	.56	16.3
	Market refuse	0	0.0	0	0.00	0.0		0	0.0	0	0.00	0.0
	Total	69 006	100.0	1 641	5.38	100.0		45 034	100.0	1 049	3.44	100.0
February	Ashes	56 100	84.2	1 403	4.62	88.5	August	35 600	75.1	890	2.92	80.9
	Rubbish	2 398	3.6	10	.03	.6		2 398	5.1	10	.03	.9
	Garbage	8 150	12.2	174	.57	10.9		9 400	19.8	200	.66	18.2
	Market refuse	0	0.0	0	0.00	0.0		0	0.0	0	0.00	0.0
	Total	66 648	100.0	1 587	5.22	100.0		47 398	100 0	1 100	3.61	100.0
March	Ashes	58 400	84.9	1 460	4.80	89.0	September	33 900	75.1	848	2.78	81.2
	Rubbish	2 344	3.4	9	.03	.6		2 507	5.6	10	.03	1.0
	Garbage	8 050	11.7	171	.56	10.4		8 750	19.3	186	.61	17.8
	Market refuse	0	0.0	0	0.00	0.0		0	0.0	0	0.00	0.0
	Total	68 794	100.0	1 640	5.39	100.0		45 157	100.0	1 044	3.42	100.0
April	Ashes	58 950	85.4	1 474	4.85	89.6	October	39 250	77.1	981	3.22	82.8
	Rubbish	2 398	3.5	10	.03	.6		2 507	4.9	10	.03	.8
	Garbage	7 600	11.1	162	51	9.8		9 150	18.0	195	.64	16.4
	Market refuse	0	0.0	0	0.00	0.0		0	0.0	0	0.00	0.0
	Total	68 948	100.0	1 646	5.39	100.0		50 907	100.0	1 186	3.89	100.0
May	Ashes	59 150	85.2	1 479	4.85	89.3	November	41 500	80.3	1 038	3.40	85.4
	Rubbish	2 398	3.5	10	.03	.6		2 224	4.3	9	.03	.7
	Garbage	7 850	11.3	167	.55	10.1		7 950	15.4	169	.55	13.9
	Market refuse	0	0.0	0	0.00	0.0		0	0.0	0	0.00	0.0
	Total	69 398	100.0	1 656	5.43	100.0		51 674	100.0	1 216	3.98	100.0
June	Ashes	40 200	78.9	1 005	3.30	84.6	December	51 850	83.3	1 296	4.25	87.7
	Rubbish	2 616	5.1	10	.03	.8		2 289	3.7	9	.03	.6
	Garbage	8 150	16.0	174	.57	14.6		8 100	13.0	173	.57	11.7
	Market refuse	0	0.0	0	0.00	0.0		0	0.0	0	0.00	0.0
	Total	50 966	100.0	1 189	3.90	100.0		62 239	100.0	1 478	4.85	100.0
Average	Ashes							47 288	80.8	1 182	3.88	85.8
	Rubbish							2 398	4.3	10	.03	.7
	Garbage							8 329	14.9	177	.58	13.5
	Market refuse							0	0.0	0	0.00	0.0
	Total							58 015	100.0	1 369	4.49	100.0

* 5½ days per week. 1 cu. yd. ashes = 1 350 lb. 1 cu. yd. garbage = 1 150 lb. 1 cu. yd. rubbish = 212 lb. 1 cu. yd. market refuse = 1 150 lb.

TABLE No. 10.—BOSTON REFUSE DISPOSAL. SHOWING AVERAGE WEEKLY QUANTITIES (CU. FT. AND TONS) OF REFUSE COLLECTED FROM **South End and Back Bay** (DISTRICTS NOS. 8 AND 9) DURING EACH MONTH OF THE YEAR, MAY, 1906, TO APRIL, 1907. (Population, 1905, 103 000.)

		Cubic Feet.		Tons.				Cubic Feet.		Tons.		
		Average Weekly.	Per Cent.	Average Weekly.	Lb.* per Capita per Day.	Per Cent.		Average Weekly.	Per Cent.	Average Weekly.	Lb.* per Capita per Day.	Per Cent.
January	Ashes	108 250	66.9	2 706	9.97	82.5	July	54 950	56.2	1 374	5.06	75.5
	Rubbish	32 722	20.2	129	.47	3.9		27 010	27.6	106	.39	5.8
	Garbage	20 800	12.9	443	1.63	13.6		15 800	16.2	337	1.24	18.7
	Market refuse	0	0.0	0	0.00	0.0		0	0.0	0	0.00	0.0
	Total	161 772	100.0	3 278	12.07	100.0		97 760	100.0	1 817	6.69	100.0
February	Ashes	109 650	69.1	2 741	10.09	83.7	August	58 450	56.3	1 461	5.38	75.6
	Rubbish	29 212	18.4	115	.42	3.5		28 449	27.4	112	.41	5.8
	Garbage	19 800	12.5	422	1.55	12.8		16 900	16.3	360	1.33	18.6
	Market refuse	0	0.0	0	0.00	0.0		0	0.0	0	0.00	0.0
	Total	158 662	100.0	3 278	12.06	100.0		103 799	100.0	1 933	7.12	100.0
March	Ashes	109 700	68.3	2 743	10.09	83.5	September	56 150	55.7	1 404	5.17	74.7
	Rubbish	31 196	19.4	122	.45	3.7		27 272	27.1	107	.40	5.7
	Garbage	19 650	12.3	418	1.54	12.8		17 300	17.2	368	1.35	19.6
	Market refuse	0	0.0	0	0.00	0.0		0	0.0	0	0.00	0 0
	Total	160 546	100.0	3 283	12.08	100.0		100 722	100.0	1 879	6.92	100.0
April	Ashes	102 350	66.8	2 559	9.42	82.5	October	67 250	56.5	1 681	6.19	75.3
	Rubbish	31 610	20.6	124	.46	4.0		31 501	26.4	124	.46	5.4
	Garbage	19 350	12.6	412	1.52	13.5		20 400	17.1	434	1.60	19.3
	Market refuse	0	0.0	0	0.00	0.0		0	0.0	0	0.00	0.0
	Total	153 310	100.0	3 095	11.40	100.0		119 151	100.0	2 239	8.25	100.0
May	Ashes	80 550	62.7	2 014	7.41	79.5	November	80 400	62.6	2 010	7.40	79.3
	Rubbish	28 558	22.3	112	.41	4.4		28 536	22.2	112	.41	4.4
	Garbage	19 200	15.0	409	1.51	16.1		19 550	15.2	416	1.53	16.3
	Market refuse	0	0.0	0	0.00	0.0		0	0.0	0	0.00	0.0
	Total	128 308	100.0	2 535	9.33	100.0		128 486	100.0	2 538	9.34	100.0
June	Ashes	64 100	56.9	1 603	5.90	76.0	December	101 800	66.0	2 545	9.37	81.5
	Rubbish	30 356	26.9	119	.44	5.6		31 087	20.2	122	.45	3.9
	Garbage	18 300	16.2	390	1.44	18.4		21 300	13.8	454	1.67	14.6
	Market refuse	0	0.0	0	0.00	0.0		0	0.0	0	0.00	0.0
	Total	112 756	100.0	2 112	7.78	100.0		154 187	100.0	3 121	11.49	100.0
Average	Ashes							82 800	63.0	2 070	7.62	79.8
	Rubbish							29 792	22.6	117	.43	4.5
	Garbage							19 030	14.4	405	1.50	15.7
	Market refuse							0	0.0	0	0.00	0.0
	Total							131 622	100.0	2 592	9.55	100.0

*5½ days per week. 1 cu. yd. ashes = 1 350 lb. 1 cu. yd. garbage = 1 150 lb. 1 cu. yd. rubbish = 212 lb. 1 cu. yd. market refuse = 1 150 lb.

TABLE No. 11. — BOSTON REFUSE DISPOSAL. SHOWING AVERAGE WEEKLY QUANTITIES (CU. FT. AND TONS) OF REFUSE COLLECTED FROM **North and West Ends** (DISTRICT No. 10) DURING EACH MONTH OF THE YEAR, MAY, 1906, TO APRIL, 1907. (Population, 1905, 73 000.)

		Cubic Feet.		Tons.				Cubic Feet.		Tons.		
		Average Weekly.	Per Cent.	Average Weekly.	Lb.* per Capita per Day.	Per Cent.		Average Weekly.	Per Cent.	Average Weekly.	Lb.* per Capita per Day.	Per Cent.
January	Ashes	87 500	67.1	2 188	9.97	82.8	July	61 100	63.1	1 528	6.97	81.4
	Rubbish	26 531	20.3	104	.48	4.0		23 740	24.5	93	.42	4.9
	Garbage	10 400	8.0	221	1.01	8.4		9 550	9.9	202	.93	10.9
	Market refuse	6 030	4.6	128	.58	4.8		2 410	2.5	52	.24	2.8
	Total	130 461	100.0	2 641	12.04	100.0		96 800	100.0	1 875	8.56	100.0
February	Ashes	91 350	68.0	2 284	10.42	83.5	August	66 600	61.5	1 666	7.58	78.4
	Rubbish	26 574	19.8	104	.48	3.8		24 656	22.9	97	.44	4.6
	Garbage	10 050	7.5	214	.97	7.8		10 000	9.2	213	.97	10.0
	Market refuse	6 360	4.7	136	.61	4.9		6 980	6 4	149	.68	7.0
	Total	134 334	100.0	2 738	12.48	100.0		108 236	100.0	2 125	9.67	100.0
March	Ashes	86 650	65.8	2 166	9.89	81.9	September	65 400	60.2	1 635	7.46	77.3
	Rubbish	27 304	20.8	108	.49	4.1		25 310	23.3	100	.46	4.8
	Garbage	10 550	8.0	225	1.02	8.4		9 950	9.2	212	.96	10.0
	Market refuse	7 050	5.4	150	.68	5.6		7 920	7.3	169	.76	7.9
	Total	131 554	100.0	2 649	12.08	100.0		108 580	100.0	2 116	9.64	100.0
April	Ashes	85 300	66.0	2 132	9.72	82.4	October	71 300	62.1	1 783	8.14	79.5
	Rubbish	27 850	21.5	110	.50	4.2		26 596	23.2	104	.48	4.7
	Garbage	9 750	7.5	208	.95	8.1		10 150	8.8	216	.97	9.5
	Market refuse	6 430	5.0	137	.62	5.3		6 780	5.9	144	.65	6.3
	Total	129 330	100.0	2 587	11.79	100.0		114 826	100.0	2 247	10.24	100.0
May	Ashes	71 100	61.9	1 777	8.11	78.9	November	74 200	63.0	1 855	8.46	80.5
	Rubbish	26 509	23.1	104	.48	4.7		27 042	23.5	109	.50	4.8
	Garbage	10 050	8.7	214	.98	9.5		9 750	8.3	208	.95	9.0
	Market refuse	7 250	6.3	154	.71	6.9		6 100	5.2	132	.60	5.7
	Total	114 909	100.0	2 249	10.28	100.0		117 752	100.0	2 304	10.51	100.0
June	Ashes	66 500	61.0	1 663	7.60	78.2	December	81 800	66.0	2 045	9.32	82.3
	Rubbish	25 288	23.2	100	.45	4.6		26 356	21.3	104	.47	4.1
	Garbage	10 050	9.2	214	.97	10.0		9 850	7.9	210	.96	8.5
	Market refuse	7 180	6.6	153	.70	7.2		5 960	4 8	127	.58	5.1
	Total	109 018	100.0	2 130	9.72	100.0		123 966	100.0	2 486	11.33	100.0
Average	Ashes							75 600	63.8	1 894	8.63	80.7
	Rubbish							26 200	22.2	103	.47	4.4
	Garbage							10 000	8.5	213	.97	9.1
	Market refuse							6 370	5.5	136	.62	5.8
	Total							118 170	100.0	2 346	10.69	100.0

* $5\frac{1}{2}$ days per week. 1 cu. yd. ashes = 1 350 lb. 1 cu. yd. garbage = 1 150 lb. 1 cu. yd. rubbish = 212 lb. 1 cu. yd. market refuse = 1 150 lb.

The foregoing tables indicate that the quantity of ashes and house dirt per capita collected daily throughout the city was greatest in the North and West Ends and in the South End and Back Bay, the districts which include the business portions of the city and the larger hotels. Next to these districts, the quantity was greatest in the suburban residential districts of Brighton and West Roxbury. Practically all of the combustible waste and rubbish is collected in the downtown districts.

The quantity of garbage is greatest per person in the South End and Back Bay (Districts 8 and 9) and next largest in the North and West Ends (District 10), the districts of the great hotels. It will be noted that the quantity of garbage collected in East Boston is much greater per capita than that collected in South Boston or Charlestown. The explanation offered is that East Boston, being a very large shipping point, contains a large floating population in proportion to the population of the district, including sailors and employees of vessels, not recorded in the census.

In the following table is given the average daily quantity of street and catch-basin cleanings collected in the various districts for the year 1906 in loads, cubic feet and tons; also in pounds per capita.

Comparison of Quantities of Waste and Refuse Collected in the Cities of Boston and New York.

Before leaving the question of the quantity of wastes it will be of interest to compare the quantity of wastes collected per capita in the city of Boston with those collected in the boroughs of Manhattan and the Bronx, kindly furnished by Mr. Macdonough Craven, recently street commissioner of the city of New York. These figures are for ashes, rubbish and garbage. They show a very remarkable similarity in the total quantity of such wastes collected in the two cities.

Methods of Disposal of Municipal Waste and Refuse in the City of Boston.

Ashes and House Dirt. — Of the total amount of 466 000 tons of this material collected in the entire city in the year 1906, 132 000 tons, or 28 per cent., were delivered at Fort Hill Wharf on Atlantic Avenue, discharged into scows and dumped at sea, off the mouth of the harbor. All of the remainder of this waste and refuse is disposed of by dumping it upon low grounds in various parts of the city.

TABLE No. 12. — BOSTON REFUSE DISPOSAL.

TABLE SHOWING AVERAGE DAILY* QUANTITIES OF STREET CLEANINGS AND CATCH-BASIN CLEANINGS COLLECTED IN THE CITY OF BOSTON DURING 1906.

Sanitary District.		South Boston.	East Boston.	Charles-town.	Brighton.	West Roxbury.	Dor-chester.	Roxbury.	South End and Back Bay.	North and West Ends.	Entire City.
District Number.		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8 and 9)	(10)	
Population (1905).		75 053	51 334	39 983	21 806	33 352	84 417	110 850	98 822	79 763	595 380
Street Cleanings.	Loads,	60	24.2	33.4	25.7	17.5	30.0	33.4	119.2	65.1	408.5
	Cu. Ft.,	3 000	1 213	1 672	1 288	875	1 500	1 673	5 975	3 255	20 451
	Tons,	55.5	22.5	30.9	23.8	16.2	27.8	31.0	110.5	60.2	378.3
	Lb., †	1.48	.88	1.55	2.18	.97	.65	.56	2.24	1.51	1.27
Catch-Basin Cleanings.	Loads,	8.9	8.2	4.9	5.0	6.0	25.1	27.1	12.3		97.5
	Cu. Ft.,	266	245.5	140.3	151.0	181.0	756.0	814.0	371.0		2 930.8
	Tons,	6.65	6.12	3.65	3.78	4.52	18.90	20.35	9.28		73.27
	Lb., †	.177	.239	.18	.346	.271	.448	.368	1.88		.246
Total.	Loads,	68.9	32.4	38.3	30.7	23.5	55.1	60.5	196.6		506.0
	Cu. Ft.,	3 266	1 458.5	1 818.3	1 439.0	1 056.0	2 256.0	2 487.0	9 601.0		23 381.8
	Tons,	62.15	28.62	34.55	27.58	20.72	46.70	51.35	179.98		451.57
	Lb., †	1 657	1.119	1.73	2.526	1.241	1.098	0.928	5.63		1.516

* $5\frac{1}{2}$ days per week. † Lb. per capita per day. NOTE. — 1 cu. yd. street cleanings = 1 000 lb. 1 cu. yd. catch-basin cleanings = 1 350 lb.

TABLE No. 13. — BOSTON REFUSE DISPOSAL. COLLECTION OF REFUSE IN THE CITIES OF BOSTON* AND NEW YORK† (1906).

	Tons (2 000 Lb.).				Per Cent of Total by Weight.		Lb. per Capita per Day. §	
	Total for Year.		Average per Day. §					
	Boston.	New York.	Boston.	New York.	Boston.	New York.	Boston.	New York.
Ashes	466 100	1 903 500	1 628	6 654	87.29	82.04	5.470	5.582
Rubbish	12 198	192 496	42	673	2.28	8.30	.143	.565
Garbage	55 700	224 250	195	784	10.43	9.66	.653	.658
Total	533 998	2 320 246	1 865	8 111	100.00	100.00	6.266	6.805

* Population (1905), 595 380.

† BOROUGHS OF MANHATTAN AND THE BRONX.
Population (1905).

Manhattan	2 112 380
Bronx	271 630
Total	2 384 010

§ $5\frac{1}{2}$ days per week.

NOTE. — 1 cu. yd. ashes = 1 350 lb.
1 ,, rubbish = 212 ,,
1 ,, garbage = 1 150 ,,

Combustible Waste and Refuse. — Of the total quantity of waste and refuse, so called, collected in the city, amounting to 3 108 000 cu. ft. in the year 1906, 2 829 000 were delivered to an incinerator plant on Hecht Wharf and the remainder deposited on dumps in various parts of the city, where a part of it was burned.

Garbage. — Of the 55 700 tons of house offal collected in the entire city in 1906, 41 960 were conveyed to scows at the Fort Hill and Albany Street wharves — 17 660 tons to the former and 24 300 tons to the latter — and towed to the garbage reduction plant at Spectacle Island. The remainder — 13 740 tons — collected in East Boston, Brighton, West Roxbury and Dorchester, was sold for the feeding of swine.

During the past year the sale of offal from Dorchester for the feeding of swine has been discontinued, and this offal is now delivered at Fort Hill Wharf. Difficulty has been experienced on account of the disposal of offal from East Boston for the purpose of feeding swine, and it is likely that that method of disposal will soon be discontinued and the offal from that district delivered to the reduction plant at Spectacle Island.

The works for the disposal of garbage in the city of Boston were *originally* constructed on the mainland, and, though located more than a mile from any dwellings, yet nuisance was severe, and the plant was subsequently removed to Spectacle Island. References to serious nuisance from this plant in its present location have been made in the newspapers during the past summer.

Street Cleanings. — Of the 5 850 000 cu. ft. of street cleanings collected in the entire city, 1 965 000, or 34 per cent., are delivered to Fort Hill Wharf and dumped at sea. The remainder is dumped with the ashes and other refuse for the filling of low lands.

Catch-Basin Cleanings. — Cesspool and catch-basin cleanings amounted in 1906 to 837 000 cu. ft., of which 190 000, or 23 per cent., were shipped at Fort Hill Wharf and dumped at sea, while the remainder was dumped with the other refuse in the low grounds about the city.

Market Refuse. — The market refuse, amounting to about 8 600 tons, was dumped into scows at Fort Hill Wharf and disposed of at sea. A considerable quantity of market refuse is, however, disposed of on the land dumps in various parts of the city.

Dumping on Land.

The great bulk of the refuse material disposed of from the

city is dumped upon the low grounds, and at the present time the number of such dumping places in use in the city of Boston is in the neighborhood of 60.

The total number of loads of waste and refuse dumped at these places was counted during certain weeks in the month of June, 1907, the results showing that at the largest of these dumps 477 loads of material were disposed of in a single week. At the next largest dump 282 and 283 loads respectively were disposed of in different weeks. At ten other dumps more than 200 loads per week were disposed of, and at eight others between 100 and 200 loads per week were disposed of.

These dumps are used in many places as a playground by children and are a source of constant annoyance to the health department from foul odors and especially from smoke caused by frequent fires. They are usually very unsightly and at times of high winds many acres of ground are sometimes covered by flying debris, chiefly paper, from a large dump.

[Note. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by August 1, 1908, for publication in a subsequent number of the Journal.]

SEWERAGE STATISTICS.

Collected and Tabulated by the Sanitary Section of the Boston Society of Civil Engineers.

[Presented to the Sanitary Section of the Boston Society of Civil Engineers, May 6, 1908, by a committee consisting of Harrison P. Eddy, Bertram Brewer and Charles Saville.]

THE need of better methods of keeping records relative to the operation of both sewerage systems and sewage disposal works is acknowledged by all. At the present time it is almost impossible to obtain from the annual reports of sewer departments statistics which are of any value in comparing the work of such departments in different cities, and it is with the idea of improving these conditions that the Sanitary Section of the Boston Society of Civil Engineers has taken up the matter of collecting available data along these lines and encouraging the adoption of a better and more uniform system of keeping records.

A set of questions in pamphlet form was first prepared including all items of general interest pertaining to the construction and operation of sewerage systems and sewage disposal plants. The pamphlets were sent to a number of cities with the request that the blanks be filled in and the pamphlets returned to the Society. As a result, some twenty-five municipalities located in Massachusetts and neighboring states have contributed a large amount of interesting data.

In some cases, without doubt, this has meant a good deal of work, and the committee wishes to take this opportunity of expressing its appreciation to those who have been kind enough to collect and prepare the desired information. We cannot help feeling, however, that the work has been worth while. In some cases it has been evident that but few accurate records of any kind have been kept, while in other instances the data are probably kept in such shape that they are of little real value. Both of these points have doubtless been brought home to those who have given their time in preparing the pamphlets.

In attempting to collect the data for 1906, only two dozen replies were received, but we hope to hear from at least double this number in 1907, and urge a hearty coöperation on the part of those who are in a position to help in the work.

We would also suggest that the yearly summary of statistics as prepared for this Society be inserted in the annual reports of the sewer departments in the various municipalities. Worcester, Mass., Newton, Mass., and possibly others have already adopted this suggestion.

The information thus far obtained has been summarized in the accompanying tables, which are self-explanatory. The Society hopes to publish similar data for subsequent years, and will welcome suggestions relative to the best method of arranging and tabulating this information.

Statistics for 1906.

In addition to the data presented in the tables considerable information has been obtained relative to the methods employed in the several municipalities for the flushing and cleaning of sewers.

Flushing. — In fifteen instances the pipes are flushed by means of direct connections or special hose connections with the water mains. Flush tanks are used in four places, and reports from two cities state that no regular method of flushing is followed. In one case the desired result is effected by backing up the sewage in the manholes and then allowing it to flush rapidly through the pipes.

Cleaning. — The methods employed for the cleaning of sewers vary to a considerable extent. As it has been found rather difficult to make a summary of this information, it has been given in full.

Arlington, Mass. A special kind of brush is used which is drawn through the sewer from one manhole to another.

Dedham, Mass. Cleaning is effected by flushing and scraping.

Everett, Mass. The Healey sewer cleaning machine is used.

Fall River, Mass. The pipes are cleaned by flushing through connections with city water mains.

Fitchburg, Mass. The material accumulating in the sewers is intercepted at manholes and removed with a shovel and a pail. The Healey sewer cleaner is also used to some extent.

Gardner, Mass. The sewers are cleaned by flushing through connections with town water mains. Small sewers are also cleaned by the use of rods; and the larger ones by the use of steel buckets dragged between manholes.

TABLE SHOWING DATA (FOR THE FISCAL YEAR 1906) RELATIVE TO SEWERAGE AND SEWAGE DISPOSAL IN CERTAIN CITIES AND TOWNS IN MASSACHUSETTS AND NEIGHBORING STATES. PART I.

GENERAL

City or Town	Population (Census of 1905)	Total Area of City or Town (Sq. Miles)	Area Served by Sewerage System (Sq. Miles)	Collection System: For Sewage Only (Miles)	For Sewage and Surface Water (Miles)	For Surface Water Only (Miles)	Method of Disposal
Arlington, Mass.	9 668	5.50	1.50	26.70		6.30	Metropolitan System
Dedham, Mass.	7 774			14.00			Metropolitan System
Everett, Mass.	(a) 29 340	3.32	2.90	(d) 8.90	(d) 4.10	(d) 15.00	Metropolitan System
Fall River, Mass.	(a) 107 911	(c) 39.87			4.00		Tide Water
Fitchburg, Mass.	33 021	28.18	2.02		35.97		Nashua River
Gardner, Mass.	12 612	18.10	2.50	2.50			Settling Tank and Sand Filters
Haverhill, Mass.	37 830	32.00	1.40	3.20	31.20	0.80	Merrimac River
Hopedale, Mass.	2 048	5.34	0.50	4.18		1.5	Septic Tank and Sand Filters
Hyde Park, Mass.	14 510	4.91	2.00	21.00	0.00	[illegible]	Metropolitan System
Laconia, N. H.	(b) 9 000	18.00	2.00	20.00	0.00	7.00	Lake Winnisquam
Lawrence, Mass.	70 050	6.75	2.95		66.00	0.7	Merrimac River
Lowell, Mass.	94 889	14.20	10.00	1.00	97.5	1.50	Merrimac River
Marlborough, Mass.	14 072	21.00	1.25	24.9		5.7	Sand Filters
Nashua, N. H.	23 898	33.50	1.00		14.50	0.50	Merrimac River
New Bedford, Mass.	(a) 79 078	19.5	6.00	0.17	71.12	0.85	Tide Water (outlets)
New London, Conn.	(a) 22 000	1.50	2.00	28.00			Tide Water
Newton, Mass.	36 827	18.00	1.18	101.88		5.6	Metropolitan System
Pawtucket, R. I.	[illegible]	8.94	2.15		51.86		Part by Sand Filters, Part by Dilution
Plainfield, N. J.	18 478	6.0	[illegible]	54.14		7.20	Septic Tank and Contact Beds
Springfield, Mass.	(a) 77 000	38.00	7.00	0.18	106.16	[illegible]	Connecticut River
Waltham, Mass.	[illegible]	13.56	2.70	11.28	0.0	1.65	Metropolitan System
Watertown, Mass.	11 202	4.17	2.00	[illegible]	0.0	8.11	Metropolitan System
Westfield, Mass.	13 [illegible]	42.00	1.70	26.8		11.16	Westfield River
Worcester, Mass.	128 135	31.42	7.20	[illegible]	5.00	12.82	Chemical Precipitation and Filters

COLLECTION

City or Town	*	Linear Feet Stone	Linear Feet Brick	Linear Feet Concrete	Linear Feet Pipe	Linear Feet Extended during Year	Number of Inverted Siphons	Number of Manholes	Number of Automatic Flush Tanks	Number of Direct Connections with Water Main for Flushing	Number of Flushings of Entire System during Year	Cost of Flushing per Mile	Cost of Cleaning per Mile	Number of Stoppages	Miles of Permanent Underdrains	Number of Storm Overflows	Method of Ventilation
Arlington	A B C				141 155 2 740	758	2	576		60	6	$0.75	$4.00		3	5	Manhole covers
Dedham	A		5 400		72 545	1 000			1		1					2	Through plumbing system
Everett	A B C		1 400 11 840 400	 5 300	105 350 72 500 30 000	1 750 190 6 400	 2	630 310 220		3	2 2	12.83	5.00 93.40	6		1	Manholes
Fall River	A B C	4 500	166 207	(e) 2 633	241 068	7 020		2 364								6	Perforated manhole covers
Fitchburg	B		2 261		106 160	1 484		670									Perforated manhole covers
Gardner	A B C				118 201	8 190	1	182						2	3		
Haverhill	A B C		41 500	2 200 2 300	17 000 165 200 1 900	2 175 2 067		65 580 18								4	Manholes and catch-basins
Hopedale	A				22 900			81									
Hyde Park	A B C	 1 750		1 250	110 880 17 500	5 180 800		111	6		2			2	12		Covers, house-stacks and catch-basin openings
Laconia	A B C	2 640			107 000 36 900	1 000 1 700	[illegible]	[illegible] 50	[illegible]	9	[illegible]	0.50		30	1		Stacks through roofs
Lawrence	B C		10 600 [illegible]		228 [illegible]	11 582	1	1 175						165		11	Open outlets and perforated manhole covers
Lowell	A B C	6 12[illegible]	167 000		200 [illegible] 8 100	3 000 10 811 170		24 1				1.05	3.00			8	Perforated manhole covers
Marlborough	A				151 [illegible]	2 200		[illegible]		102	[illegible]						Manhole covers
Nashua	A B C	 700	[illegible]		25[illegible] 504 [illegible]	1 700									0.5	6	House connections
New Bedford	A B C	1 100	6 280	58	25[illegible] 250	2 437		601							4	1	Manhole covers and house connections
New London	A B C		671		147 160	1 607		671		1	4			1	2		Perforated manhole covers
Newton	A B C	 11 11[illegible]	56 168 8 100	50 2 658 15 743	170 620 220 0[illegible]	6 867 11 701	1 1	2 640 [illegible]		180	1[illegible]	9.80	25.50		64	3	Perforated manhole covers and house connections
Pawtucket	B		41 [illegible]	3 031	231 523	3 854		1 [illegible]	121	168	3	0.45	0.37	57	1.7	16	Perforated manhole covers
Plainfield	A B C		1 [illegible]	1[illegible]	190 840 12 485	14 072 520	1	2[illegible]	107	[illegible]		20.[illegible]		2	2.12		House connections
Springfield	A B C	2 [illegible]	11 [illegible]	1 164	970 11 070 700	970 6 647				1 367	20	20.28	16.08			1	Manhole covers
Waltham	A B C	 2 168	6 575 6 901	1 7[illegible]	208 888 5[illegible] 201	6 711 400	2	8		11[illegible]	2	8.10	1.30	8	[illegible]		Perforated manhole covers and house connections
Watertown	A B C		1 001	1 760	171 019 37 400	671 2 383	1 1	[illegible]		50	2	5.40		2		2	Direct through house-stacks
Westfield	A B C		21 2[illegible]		141 171 7 160	2 [illegible] 1 510	1 1	71 1					3.20	6			Through manholes
Worcester	A B C	71 17 160	71 011 18 472 57 150	2 120 [illegible]	18 [illegible] 250 [illegible] 147 840	7 106 7 944 5 855	7 [illegible]	611	7 2	25 54	1	142.16	38.1[illegible]	1	1.15	34	Only by perforated covers on manholes

HOUSE CONNECTIONS — CATCH-BASINS — DISCHARGE OF SEWAGE

City or Town	By Whom Made	Sizes (Inches in Diam.)	Number Made during Year	Linear Feet Laid during Year	Linear Feet Discontinued during Year	Total Miles in Use	Average Cost per Foot Connections Made during Year	Number of Stoppages Coming to Attention of Dept.	Number of Catch Basins	Number Catch Basins Cleaned	Av. Amt. Material Removed per Catch-Basin [cu. yds.]	Cost of Removing Material per Cubic Yard	Cost of Removing Material per Catch Basin per Year	Estimated Population Using System	Number of Buildings Connected	Daily Discharge for Year (Average Number Gallons)	Daily Discharge for Each User	Daily Quantity Factory Waste	Daily Leakage into Sewers	Daily Leakage per Mile of Sewer
Arlington	Town	5	64	3 911		11.25	$0.55	3	184		4	$0.50	$2.00	6 600	1 030					
Dedham	Contractor	5	52					2												
Everett	Licensed drain-layers	6	106	4 120		31.00	0.60	6	500	440	9	0.52	5.00	28 640	4 500	(k) 5 300 000	(k) 185			
Fall River	Licensed drain-layers	6	145	3 625				49	898	2 254	2.76	1.46	4.04							
Fitchburg	City	5	47	1 900			0.40		700		3.03	0.77	2.66	24 000	2 800	(k) 2 800 000	(k) 116			
Gardner	City	5	96	4 648		8.50	1.23	3						7 500	917					
Haverhill	Licensed drain-layers	5	88																	
Hopedale	Draper Co.	6												2 250	(o) 213	(k) 144 000				
Hyde Park	Contractor	5	123	6 028	10	3.00	0.60	4	92	80	2	0.75	1.50	7 520	1 655		(k) 70		(k) 400 000	20 000 (k)
Laconia	Licensed drain-layers	4	63	2 500				5	500	150	0.5			8 000	972					
Lawrence	By plumbers and others	6	176				0.50	75	1 100	2 840	2	0.93	6.04	67 886						
Lowell	Private contractors	5 to 8	211	10 500				59	3 364	3 364	1.50	1.00	1.50							
Marlborough	City	5	36	1 500		1.30	0.12	10	655	1 310	0.25		1.46	10 700	[illegible]	(l) 580 000 Av. (l) 1 490 000 Max. (l) 296 000 Min.	(l) 54.1 Av. (l) 139.2 Max. (l) 27.7 Min.			
Nashua	Licensed drain-layers	4 to 8	91						1 300	2 400	1			20 000						
New Bedford	City	5 to 10	522	12 046			0.48	175	945	All	4	0.90	3.60	70 000		(k) 7 000 000	(k) 95			
New London	Plumbers	6	290											17 000	2 219					
Newton	City and contractor	5 to 8	107	8 599	400	67.50	0.65	75	2 204	6 882	5.2			38 400	5 170	(k) 3 000 000 Av. (k) 6 000 000 Max. (k) 1 066 000 Min.	(k) 106 Av. (k) 212 Max. (k) 38 Min.			
Pawtucket	By property owners	6	172	4 300		17.43	0.60		1 028	1 162	1.7	(c) 1.04	(c) 1.77	[illegible]	1 184					
Plainfield	Licensed plumbers	4	261				[illegible]	3	53	53	7			17 250	2 613	(l) 1 000 000 Av. (l) 1 400 000 Max. (l) 500 000 Min.	(l) 77		(k) 400 000 Max.	
Springfield	City	6 to 8	263	6 725			0.48													
Waltham	City	4 and 5	82	3 685	147	30.22	0.42	79	400	All. Some 3 times			3.60	21 500	3 118					
Watertown	Town	4 and 5	56	1 366			0.82	13												
Westfield	Plumbers	4, 5 and 6	50					12	317	317			0.35	[illegible] 480	1 849	(k) 2 527 000	By one meas'ment			
Worcester	Licensed drain-layers	6	540	21 770	306	118.50	0.50	17	2 818	4 652	0.53	0.56	3.82	130 200		Millions (m) 11.67 Av. (m) 20.653 Max. (m) 8.619 Min.	(m) 122.0 Av. 171.8 Max. 66.7 Min.		(m) 3 127 000	(m) 23 130

* A For sewage only
B For sewage and surface water
C For surface water only

(a) Special census
(c) Land and water
(d) Acres
(e) Stone and brick
(f) 1906
(h) 1900
(i) 1904-1905
(k) Estimated
(l) Measured
(m) Measured and estimated
(o) Including factories

TABLE SHOWING DATA (FOR THE FISCAL YEAR 1906) RELATIVE TO SEWERAGE AND SEWAGE DISPOSAL IN CERTAIN CITIES AND TOWNS IN MASSACHUSETTS AND NEIGHBORING STATES. PART II

PUMPING

City or Town	Description of Plant	Power / Fuel	Kind and Grade	Av. Cost per Ton	Total Amount Pumped	Other Pumping Data
[illegible]						
[illegible] Mass.	No [illegible]	Power furnished by main power plant of The Draper Company			20,000,000	
[illegible] Mass.	2 Warren Steam Pumps Cap. 20,000 gals. per hour	[illegible] 10			115 tons	[illegible] 1,000; 16; 100 per ton [illegible]
[illegible] M.	One plant consisting of two 6" centrifugal pumps operated by two [illegible] horse power gasoline engines		Gasoline [illegible] test	$0.15	3.20 gal. gasoline	[illegible]
[illegible] R. I.						
[illegible]						
[illegible] Mass.	[illegible] pumps electrically [illegible] Shone system compressed air [illegible] three lifts			$0.0[illegible]	[illegible] mill [illegible]	[illegible] 000,000; 11.7 [illegible]

DISPOSAL

City or Town	Description of Screens	Number of Tanks	Total Capacity of Tanks (Gallons)	Av. Daily Quantity of Sewage in Tanks	Av. No. of Hours Sewage is in Tanks	Disposition of Effluent	Disposition of Sludge	Cu. Yds. Sludge per Million Gals.	How often are Tanks Emptied	Cost of Tanks	Cost of Maintenance	Kinds and Quantities of Chemicals Used per Million Gallons
[illegible]		2 Gardner 4 Templeton (k)	30,200 / 10,850			Treatment on sand filters	Fertilizer of sewer farms		1 in 2 weeks / 1 in [illegible] mos.	$1,050.00 / 5,085.00	$1,177.92	
[illegible] Mass.	Wire cloth	2	10,500	144,000	12							
[illegible] Mass.	Vertical stationary [illegible]	2	8,100	520,000	0.75	Treatment on sand filters	Sludge beds		Every week			
[illegible] M.	[illegible] wire basket											
[illegible] R. I.		2	136,468	[illegible] 720	1.4	Treatment on sand filters	Earth covered dump	120	Twice daily	$5,000.00		
[illegible]	[illegible] spaces	4	1,250,000	1,000,000	11	Contact beds	Fertilizer	1.13	Once yearly			
[illegible] Mass.	No. three [illegible] screen [illegible]	1 (j) 3	5,500,000	11,000,000	16.8	Blackstone River	Pressed dumped	110	Roughing 2-4 weeks, others, 4-8 weeks	$25,628.75	$5,900.[illegible]	0.7 lbs. lime

SEWAGE BEDS OR FILTERS

City or Town	Type	Date of Construction of Works	Cost of Beds	Total Net Filtration Area (Acres)	Number of Beds	Average Area of Beds (Acres)	Were Loam and Subsoil Removed	Character of Filtering Material	Underdrains: Depth	Underdrains: Distance apart	Average Daily Quantity of Sewage Treated (Gallons)	Average Daily Quantity per Net Acre	Maximum Daily Quantity Treated	Preliminary Treatment	Dosing Apparatus and Size of Dose	How Long does Sewage flow on the Bed	How often is Each Bed used	Method of Caring for Surface of Filters	Cubic Yards of Material Removed	Cost of Removing Same	Are Crops Raised	Amount Received for Crops	Total Cost of Maintenance	Cost of Maintenance per Million Gallons Filtered	Works Capacity
[illegible]	Sand filters	1891, 2, 3 & 6 / 1903 & 04	$15,754.00 / 15,672.00	2 / 3½	20 / 12	0.12 / 0.25	Yes		4 / 4	30 / 25				Septic tanks, coke strainers		6 h by d / 12 at nt	Alternately other day	Once per year	120 / 96	$30.00 / 48.00	No				
[illegible] Mass.	Sand filters	1900		2.35	4	.587	Yes	Sand and gravel	5							2 hours	Every 24 hours				No				
[illegible] Mass.	Sand filters	1890-98	4,517.00 [illegible]	11	18	0.7	Yes	0.34	6	50	52,000	52,000	140,000	Settling tanks and screens	50,000	3-6 hours	3 or 4 times per m.	Thoroughly cleaned 3 times a year	750	20.00	Corn		[illegible]	[illegible]	
[illegible] M.																									
[illegible] R. I.	Sand filters	1894		3.36	16	17.6	Yes	0.17	5	20	15,462	6,801	50,000	Septic tanks	By hand 10,000 gallons		Every 48 to 72 hrs.	Scraped twice annually and furrowed once	1,170	$40.50	No				
[illegible]	Contact beds	1895 1903 1904	$20,000.00	3.52	16	0.22	Yes	Broken stone, slag, clinker ½ to 1½	5 tile radiat'g from gate chamber		1,000,000	378,000	1,400,000	Screened and passed through septic tanks successively		2 hours	Twice daily	Raked around distributors monthly		About 150.00	No		[illegible]	[illegible]	1,250,000 [illegible] gallons
[illegible] Mass.	Intermittent sand filter	1889-1906	192,800.04	42.5	13	0.6	Yes	Av. 1.16ths 0.23 mm; Av. 70ths 0.15 mm; Av. 85ths 20 mm	5	15	7,500,000	5,000	9,800,000	Through grit chamber 10 x 30 x 30	Controlled by gate valves on main dikes and sub-levels gates at distributors (a)	2-4 hours	1-4 times weekly	Raked near distributors every 2-4 weeks, rest every 4-8 weeks	19,426	7,100	No		[illegible]	[illegible]	

(a) [illegible] Creek. (b) Included in Part I. (c) [illegible] Pump. (d) Includes septic tank. (f) Decrease 3%, in 1 year. (g) Without allowance for slip. (i) For experimental purposes. (j) Deposit removed about 4 times a year. (k) Two areas: one in Gardner, one in Templeton.

Hyde Park, Mass. Cleaning is done in part by flushing, and partly by the use of the Healey sewer cleaning machine.

Laconia, N. H. The sewers are cleaned by flushing through connections with city water mains.

Lawrence, Mass. Cleaning is usually done by hand.

Marlboro, Mass. The Healey sewer cleaning machine is used to some extent. Otherwise the cleaning is done by flushing through connections with city water mains.

Nashua, N. H. Very little cleaning is necessary. Most of it is done by hand or with Felton's sewer cleaning rods.

New Bedford, Mass. Cleaning is effected by flushing through connections with city water mains. Sometimes the pipes have to be dug up, but this occurs very seldom.

New London, Conn. The pipes are cleaned by means of a bucket hauled through them from one manhole to another.

Newton, Mass. Cleaning is in charge of an inspector who has a small force of men under him, He inspects and cleans the sewers as occasion may require, most of the work being done in the winter months. Grease and sludge are removed by brushes with the aid of flushing. Sand and gravel are removed by cylindrical scrapers.

Pawtucket, R. I. The sewers are cleaned by flushing through connections with city water mains and by means of a brush drawn through the sewer from one manhole to another.

Plainfield, N. J. The cleaning is effected by means of buckets and root cleaners which are drawn through the sewers on the end of jointed rods or a rope.

Springfield, Mass. Cleaning is done by means of scrapers and by flushing through connections with city water mains.

Waltham, Mass. The sewers are cleaned by means of scrapers drawn through them on the end of a rod or chain.

Watertown, Mass. The cleaning is done by means of brushes and other ordinary sewer cleaning tools.

Westfield, Mass. The Healey sewer cleaning machine is used.

Worcester, Mass. When large sewers need cleaning a sectional track is laid and the silt removed in pails to the manholes where it is hoisted out and placed in carts. In small sewers scrapers are used which are pulled through them from one manhole to another, by men, horses, or a hoisting engine, as circumstances may require. A hoisting engine has proved the most economical when it was practical to use it.

Assessments. — Methods of assessing the abutters and the rates of assessment have also been reported. The custom commonly followed in this matter of assessment appears to be that of charging the abutters according to the length of frontage along the line of sewer together with a certain amount per square foot on all land within a given distance of the street line. The rates of assessment in municipalities which have adopted this method are as follows:

City or Town.	Assessment.				
	Frontage (per Linear Foot).	Area (per Square Foot). To a Depth of			
		70 Ft.	100 Ft.	150 Ft.	180 Ft.
Arlington, Mass.	$0.28		$0.0052		
Fitchburg, Mass.	0.54–.084				
Haverhill, Mass.	0.20			$0.0040	
Hyde Park, Mass.	0.47	$0.0050			
Lawrence, Mass.			0.0065		
New London, Conn.	0.50		0.0070		
Newton, Mass.	0.15				$0.0055
Pawtucket, R. I.	0.25		0.0050		
Waltham, Mass.	60%			40%	
Worcester, Mass.	1.00–1.25				

In Gardner, Mass., the assessments are based on the extent to which the sewers are used by the abutters as well as on the length of frontage along the line of the sewer.

In Laconia, N. H., a level charge of $5.00 per house is made and the householders have to pay the cost of the connection as well.

In New Bedford, Mass., one half the cost of lateral sewers is charged to the abutters in proportion to the value of the land to a depth of 100 ft. from the street line.

At Springfield, Mass., the charge is $1.50 per front ft. for business blocks and $25.00 per dwelling house.

In Plainfield, N. J., the assessment consists of one half the average cost of laying an 8-in. sewer levied on abutters on each side of the street according to their length of frontage.

In Watertown, Mass., the cost of the house connections is paid by the property owners for work done within their premises. The cost of the work within the street lines is paid by the town.

TABLE SHOWING DATA (FOR THE FISCAL YEAR 1906) RELATIVE TO SEWERAGE AND SEWAGE DISPOSAL IN CERTAIN CITIES AND TOWNS IN MASSACHUSETTS AND NEIGHBORING STATES. PART III.

FINANCIAL

CONSTRUCTION

City or Town	Receipts: Balance of Previous Year	Receipts: Bonds Issued	Receipts: Appropriation	Receipts: Assessments	Receipts: House Connections	Receipts: Other Sources	Receipts: Total	Expenditures, Collection Works: Mains	Expenditures: Pumping Stations	Expenditures: Disposal and Purification Works	Expenditures: Balance	Expenditures: Total
Arlington, Mass.			$1,000.00	$332.38	$2,196.57	$650.80	$3,139.81	$402.00	$2,188.80	$678.92	$830.12	$4,140.84
Fitchburg, Mass.		$3,250.00		2,102.03	1,910.24		7,172.93	[illegible]			375.44	7,172.93
Gardner, Mass.	$7,[illegible]93.44	15,000.00					22,986.44	[illegible]			[illegible]	22,986.44
Haverhill, Mass.	977.88	10,000.00				4.00	11,0[illegible]7	[illegible]				[illegible]
Hyde Park, Mass.												
Laconia, N. H.	40.47		140.65				185.00	[illegible]				[illegible]
Lawrence, Mass.			13,411.61	[illegible]		[illegible]	17,855.[illegible]	17,85[illegible]				17,85[illegible] b
Marlborough, Mass.	4,060.16				1,025.47	.07	[illegible]	[illegible]	886.00		[illegible]	[illegible]
Nashua, N. H.			18,415.17				18,415.17	18,415.17				18,[illegible]1.17
New Bedford, Mass.					1,500.00			[illegible]	[illegible]			12,[illegible]
New London, Conn.		18,492.98	73,027.00	22,404.31		88.20	97,70[illegible]	[illegible]			70,641.15	97,707.88
Newton, Mass.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		13,4[illegible]15	[illegible]
Pawtucket, R. I.	[illegible]		[illegible]	[illegible]		10.[illegible]	22,8[illegible]6.10		11,77[illegible]		11,0[illegible]	22,8[illegible]6.10
Plainfield, N. J.								[illegible]	106.64 (deficit)	[illegible]		
Springfield, Mass.			25,000.00	[illegible]	[illegible]	[illegible]		10,744.[illegible]	[illegible]		Paid from street Dept. funds	
Waltham, Mass.	15,680.02	25,000.00	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		20,206.44	[illegible]
Watertown, Mass.	8.31		12,000.00		404.53		12,40[illegible]	[illegible]	[illegible]			
Westfield, Mass.	34.78		[illegible]			[illegible]	18,227.14	14,177.[illegible]			[illegible]	18,227.14
Worcester, Mass.	[illegible]	30,000.00	42,900.00	[illegible]		17,110.[illegible]	[illegible]	[illegible]		17,[illegible]	[illegible]	102,298.53

MAINTENANCE AND OPERATION

City or Town	Receipts: Balance of Previous Year	Receipts: Appropriation	Receipts: Assessments	Receipts: Other Sources	Receipts: Total	Expenditures: Administration	Expenditures: Repairs	Expenditures: Cleaning Sewers	Expenditures: Cleaning Catch Basins	Expenditures: Flushing Sewers	Expenditures: Pumping	Expenditures: Disposal or Purification	Expenditures: Unclassified Expenses	Expenditures: Balance	Expenditures: Total	Interest on Bonds	Sinking Fund
Arlington, Mass.								$678.76									
Fitchburg, Mass.		$7,000.00		$1,007.67	$8,007.67		$507.67	$104.25	$1,710.23	$41[illegible]			$[illegible]71.04		$[illegible]007.17		$1,500.00
Gardner, Mass.	$758.65	1,000.00		97.50	1,856.15					187.9[illegible]		$1,137.[illegible]	[illegible]	$44[illegible].10	1,85[illegible]		
Haverhill, Mass.		1,000.00	$[illegible]233.72	303.48	[illegible]								[illegible]82.71		[illegible]71		
Hyde Park, Mass.																	
Laconia, N. H.	$647.80	1,000.00	365.00		1,012.80	$500.00				260.00					800.00		
Lawrence, Mass.					11,088.90	1,460.41	550.1[illegible]	70[illegible].45	[illegible]808.00					1,11[illegible]	11,088.[illegible]		
Marlborough, Mass.		2,000.00	8,521.8[illegible]		10,5[illegible]						$61.29	[illegible]	[illegible]26.44	[illegible]	10,[illegible]	$11,480.00	10,[illegible]00.00
Nashua, N. H.		61.50			61.50		61.50								61.50		
New Bedford, Mass.						1,006.76	11.8[illegible]	[illegible]	[illegible]8.77						12,[illegible]8.00		
New London, Conn.	188.61	11,000.00	23,784.00	16.41		[illegible]802.40											
Newton, Mass.		6,1[illegible]		11,027.40	17,[illegible]	106.19	[illegible]			1,500.00	177.70	[illegible]	[illegible]	[illegible]	17,[illegible]	[illegible],130.00	1[illegible],000.00
Pawtucket, R. I.		11,2[illegible].80		540.7[illegible]	17,[illegible]	2,1[illegible]	[illegible]	2,[illegible]41.1[illegible]	[illegible]04			[illegible]51.20	540.63	51.05	17,[illegible]	[illegible]77.00	1,[illegible]04.13
Plainfield, N. J.		1,400.00		592.38	1,792.38	1,200.00		17.44		[illegible]		[illegible]	487.11	22.40	[illegible]	[illegible]27.00	
Springfield, Mass.						[illegible]202.63	[illegible]301.81	1,41[illegible]	1,000.[illegible]	1,[illegible]01			[illegible]71	[illegible]02	[illegible]04		
Waltham, Mass.		1,450.8[illegible]			1,430.96	[illegible]	[illegible]	[illegible]77		[illegible]		[illegible]	[illegible]	5.10	1,430.9[illegible]	20,842.1[illegible]	[illegible]250.00
Watertown, Mass.								216.85									
Westfield, Mass.	4.01	1,500.00		181.72	1,7[illegible]			1,127.[illegible]	181.7[illegible]					[illegible]70	1,7[illegible]		
Worcester, Mass.	161.18	8,000.00		1,191.50	88,293.10	1,01[illegible]	[illegible]	4,58[illegible]	30,106.[illegible]	1,06[illegible]	1,011.00	20,71[illegible]	[illegible]500.38	14[illegible]2	[illegible]	[illegible]	1[illegible]08

GENERAL

City or Town	Total Cost Collecting Mains	Total Cost Pumping System	Total Cost Disposal Works	Total Cost Works to Date	Bonded Debt at Date	Value Sinking Fund at Date	Average Rate of Interest on Bonds, Per Cent	Per Cent of Cost of Systems Assessed on Abutters
Arlington, Mass.	$288,372.29 a			$288,372.29 a	$114,500.00		4	45½
Fitchburg, Mass.	384,568.41			384,565.41	78,430.00	$28,000.00	3½	77
Gardner, Mass.	230,508.65		$22,106.00 d	252,614.65			4	95
Haverhill, Mass.								35
Hyde Park, Mass.					163,000.00		4	50
Laconia, N. H.	150,000.00			150,000.00	117,000.00		4	
Lawrence, Mass.	1,176,152.00			1,176,152.00	177,000.00		4	22½
Marlborough, Mass.	[illegible]	$[illegible]020.00	[illegible]	[illegible]	287,000.00	18,551.[illegible]	4	
Nashua, N. H.								
New Bedford, Mass.				1,095,508.00	815,000.00		3.81	50 of lat. sewers
New London, Conn.	540,580.73				675,000.00		4	
Newton, Mass.	1,7[illegible]	1,[illegible]00.00		1,77[illegible]	1,7[illegible],000.00	[illegible]41.00	[illegible]	[illegible]
Pawtucket, R. I.	[illegible]			[illegible]	875,000.00	1,[illegible]04.13	4	2[illegible]
Plainfield, N. J.	17[illegible]		113,187.00	[illegible]	125,000.00 e	[illegible]000.00 h	4	
Springfield, Mass.	1,[illegible]78			1,34[illegible]178.78	233,000.00	[illegible]248.24		25
Waltham, Mass.	129,0[illegible]		Met.	129,0[illegible]	211,000.00	[illegible]200.00	4	50
Watertown, Mass.	274,[illegible]75.29		Met.		70,000.00		4	
Westfield, Mass.	250,042.72			250,042.72	112,000.00		4	
Worcester, Mass.	1,011,036.42	25,026.17	620,000.00	1,656,062.27	1,721,000.00	541,057.81	3½	[illegible]

* Includes payment for maintenance of joint disposal works. † Including reconstruction [illegible]. b Includes deficit of $702 for 1905. Expended for hose. a Includes $1094.00 for ½ [illegible] coke strainers. c [illegible]. d Bonds retired $1000. e Sanitary sewers only. h Bonds substituted for outstanding notes. g Includes $1497.98 for litigation on account of purification. † Pumps only.

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OBITUARY.

William Vaughan Moses.

MEMBER BOSTON SOCIETY OF CIVIL ENGINEERS.

WILLIAM VAUGHAN MOSES, the son of Dr. Thomas Freeman Moses and Hannah Cranch Moses, both of New England birth and ancestry, was born in Springdale, near Cincinnati, Ohio, on April 20, 1869. His parents moved the next year to Urbana, Ohio, where his father became professor of natural sciences at Urbana University.

Obtaining his preparatory education in the Urbana schools, William entered the University of Michigan, took the course in Mechanical Engineering, and graduated in the class of 1889.

After graduation he spent four years in Cleveland and Philadelphia with S. T. Wellman, working on the design and construction of blast furnaces and steel-making machinery. In 1893, he came to Cambridge and was appointed instructor in Mechanical Drawing and Machine Design at Harvard University, a position he held for eight years. At the expiration of this time he resigned to re-enter active professional work. After a year spent with the Wellman Seaver Engineering Company, as superintendent of construction on a foundry and furnace plant in Columbus, Ohio, he entered the Case School of Applied Science at Cleveland and took a year's course in electrical engineering. The following summer he visited England, and on his return in the fall of 1903, he entered the service of the General Electric Company at Lynn, Mass., where he was engaged in the design of steam turbines and where he remained until the time of his death.

In 1896, he married Mabel B. Snow, of Cambridge, Mass., who, together with his parents, four brothers and a sister, survive him. The illness which caused his death on April 14, 1908, was due to an ulcer of the stomach, and lasted but a short week.

Kindly of heart, modest and upright in character, a stanch friend, he lived a simple life, ever faithful to his duties, and to the tenets of the faith he held, that of the Swedenborgian or New Church.

F. LOWELL KENNEDY, *Committee.*

ASSOCIATION OF ENGINEERING SOCIETIES.

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PLANS, SPECIFICATIONS AND ESTIMATES OF THE COST OF BUILDING IN DETROIT AN EXACT DUPLICATE OF THE GREAT PYRAMID OF GIZEH.

BY E. S. WHEELER, MEMBER OF THE DETROIT ENGINEERING SOCIETY.

The President and Members of the Society: I wish to make some justification of, or if that is not possible, some apology or excuse for, the paper I shall read to-night.

First, I am older than the most of you and some privileges go with age; again, you either intentionally or inadvertently made me your president. In addition to the salary, there are certain privileges, exemptions and liberties that go with the office, and to-night I shall claim them all.

You members of the Engineering Society are busy men. James J. Hill once said to me, "Engineers have my highest regard; they are the men that do things." *You* are the men that are doing things in Detroit. If you should stop doing things, the city would be without buildings, without roads, ships or transportation, without light, without water and almost without hope. Each one of you has his special work and is pushing it with the most approved theories and the latest appliances. If a new and valuable discovery is made in your special field it must not be a month, or a week or a day old before you are using it for its full value, and not infrequently you furnish the new thing yourself and lead the advance. Now when any of you prepare a paper for this society it is informed with the best theories, latest results, numberless experiments, crucial tests, exact weights and measures, and your own final conclusions. To listen to and grasp such a paper require alert faculties

and close attention. Sometimes it makes me dizzy, and I get behind and am dissatisfied because my wits are not nimble enough to keep up with the theme and its logic and my memory is not comprehensive enough to retain the results. I remember that "all work and no play makes Jack a dull boy"; therefore that we may have some play mixed with our busy days, I have prepared a whimsical paper that will not require close attention or logical analysis, but rather the free use of fancy and imagination, and while it may *bore* you to listen to it, it will not *tire* you to understand it. I will say in advance that the paper has no purpose and will be entirely useless to you modern, practical, hustling engineers. The paper is entitled "Plans, Specifications and Estimates of the Cost of Building in Detroit an Exact Duplicate of the Great Pyramid of Gizeh." The present condition of the Egyptian pyramid is so nearly complete that numerous and exact measurements of all its parts have been made, so that the character and amount of all the material can be correctly given. The cost of labor and material for the Detroit pyramid will be estimated for this locality and the present time, and should be as nearly correct as estimates of the cost of large masses of masonry usually are. I shall call upon imaginations, yours and mine, for the scenes surrounding the Egyptian pyramid at the time of its building. I shall call upon fancy, yours and mine, for the methods, time and cost of building the old pyramid. I shall also call upon imaginations, yours and mine, to depict the appearance of the Detroit pyramid after it has been completed. In this the artist has aided our imaginations by giving us one view of the pyramid as it will appear from the deck of a boat in the middle of the Detroit River.

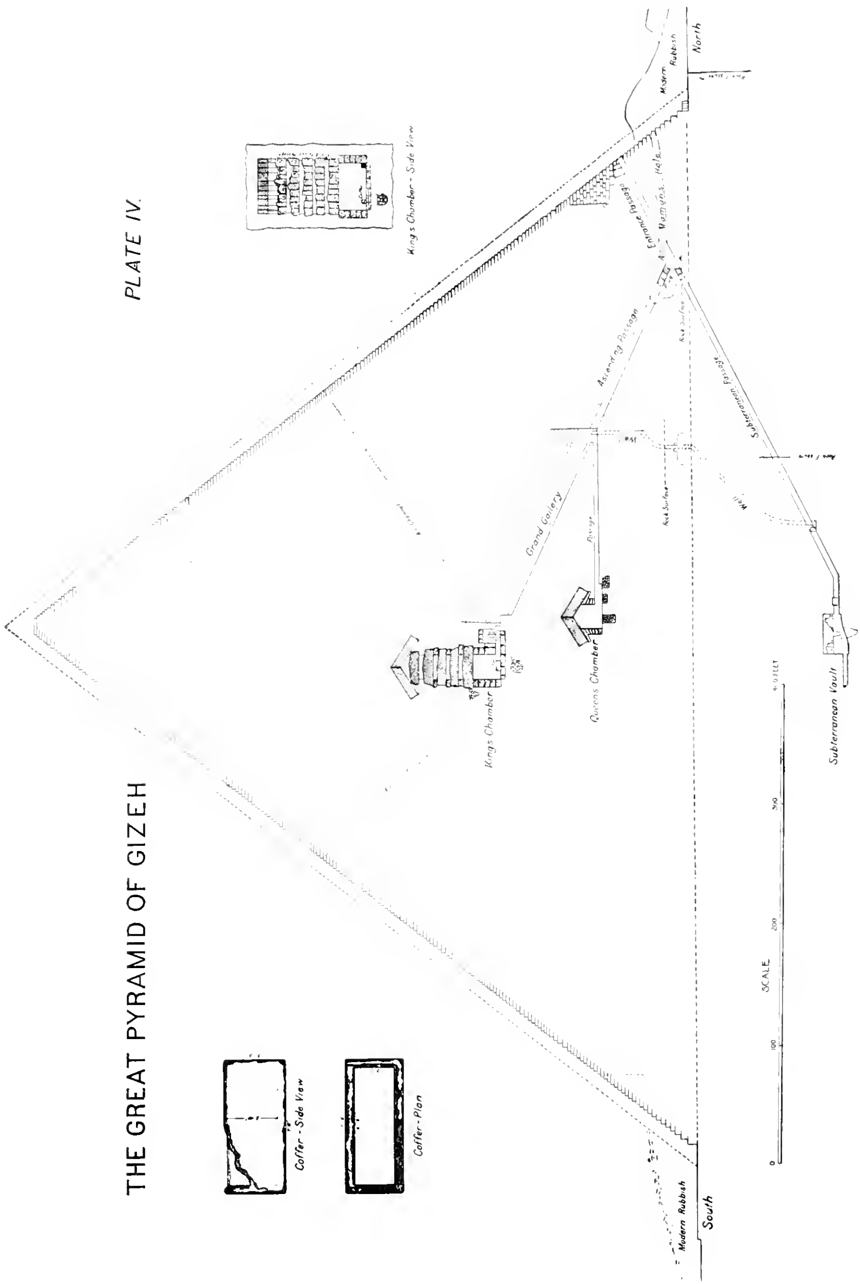
The selection of a site for the Detroit pyramid is first in order. It should be historic ground; therefore the place of Cadillac's village of 1701, the site of the fort that was besieged by Pontiac in 1763 and surrendered by Hull in 1813, has been chosen. The map, Plate I, shows the location with respect to the modern streets and buildings. The earliest authentic picture of this locality is shown on Plate II; its date is 1796. This picture and the maps were obtained from Mr. C. M. Burton, who is with us this evening. I will ask Mr. Burton to give you a few moments' talk upon their origin and authenticity. [Mr. Burton said: "The picture, Plate II, is an inset on a map of Detroit River, made in 1796 under the direction of General George Henry Victor Collot, an officer in the army of Napoleon. The original map was until lately hanging in the Department of Marine in the

city of Paris. A description of it is given in Parkman's 'Conspiracy of Pontiac.' "] A copy of the map is in possession of Mr. Burton. The map, Plate I, was compiled from early maps, descriptions found in old deeds, locations of streets, etc. [Mr. Burton exhibited a thick portfolio of original documents, all dated in the seventeenth century, many of which were used in the preparation of the map.] For these historical reasons the site finally chosen is as shown on the map, Plate I. The apex of the Detroit pyramid will be directly above the intersection of Fort and Shelby streets, and since the base of the pyramid is 759 ft. square, the structure will occupy something more than the four blocks that corner on Fort and Shelby.

The second thing in order is the foundation. The pyramid of Gizeh is built on solid rock. In order to have the Detroit pyramid equally stable, it will be necessary to build a foundation of concrete down to the rock, which is here about 120 ft. below the surface. A prism of concrete 759 ft. square and 120 ft. deep would contain about 2 600 000 cu. yd. The cost of such a foundation and a site will not be considered here, because it is believed that by the time our finances are in such a shape that the Society can without inconvenience present Detroit with such a pyramid, the city will contribute the site and foundation. We can now proceed with the specifications and estimates of the pyramid proper.

The first paragraph of the specifications is as follows: "The Detroit pyramid shall be a complete and exact copy of the pyramid of Gizeh as it was when first built and before it had been broken into and desecrated by early barbarian kings or later civilized antiquarians. The material of the Detroit pyramid must, where possible, be the same as that of the old; if not, it must be equally good, as determined by the Detroit Engineering Society."

This paragraph practically covers all of the requirements. The remaining one hundred and eight paragraphs merely describe the details of the old pyramid and prescribe them for the new. I will, therefore, not read them, but give a brief description of the old pyramid, so that you will readily understand what the remaining specifications must necessarily be. Plate IV is a section through the old pyramid. The cutting plane is vertical, parallel to the east and west sides, and 24 ft. west of the center. It happens that this plane passes through all of the rooms and passages that were originally built in the pyramid. There are some forced passages and excavations made by explorers and


THE GREAT PYRAMID OF GIZEH
PLATE IV.
Kings Chamber - Side View
Coffer - Side View
Coffer - Plan
Kings Chamber
Queens Chamber
Grand Gallery
Passage
Ascending Passage
Entrance Passage
Subterranean Passage
Subterranean Vault
Well
Rock Surface
Modern Rubbish
North
Modern Rubbish
South
SCALE
0
100
200
300

marauders which are not wholly in this plane. These will be described later.

The entrance is on the north side, about 60 ft. above the base and 20 ft. east of the middle. The entrance passage is about 3.5 ft. wide and 4 ft. high, and descends at an angle of 26 degrees. The first 105 ft. is through the masonry of the pyramid. The remaining 270 ft. has been quarried through the living rock. The lower end of this passage opens into the eastern side of a chamber called the " vault " and passes beyond it a distance of about 50 ft. when it stops abruptly and in an apparently unfinished condition. This chamber is 28 ft. wide, 46 ft. long, and averages about 8 ft. high. It is rough, unfinished, and resembles a portion of a deserted mine. Its center is directly under the apex and 100 ft. below the base of the pyramid. In the Detroit pyramid this chamber will be 100 ft. below the pavement of Shelby and Fort streets. You will see by the drawing that it will be about 80 ft. below the surface of the river. It will be entirely in the concrete foundation. This is the only part where the Detroit pyramid will differ from the old one. For some reason this room was left unfinished in the old pyramid. I think we will have ours neatly finished and decorated, so that the treasurer of the Engineering Society can use it for a quiet place to count his money.

About 90 ft. from the entrance the ascending passage begins. It opens through the roof of the descending passage, is of the same size and rises at the same angle, and lies in the same vertical plane.

After a distance of 128 ft. this passage divides into two, one of which continues southward, horizontally, for 126 ft., where it enters a room known as the " Queen's Chamber." The other part continues on in the original direction, but its height is suddenly increased from 4 to 28 ft. Through this part of its course it is called the " Grand Gallery." After 157 ft. it terminates in a low, horizontal and somewhat complicated passage, which leads into the principal room of the pyramid, known as the " King's Chamber." This room is 17 ft. wide, 34 ft. long and 19 ft. high. The roof is flat and covered with granite slabs or beams which reach from one side to the other. The sides are also of granite slabs. In the west side of this room stands a heavy stone box, believed to be a sarcophagus. The present condition of the sarcophagus is shown in this sketch. It is made from one solid block of red granite. The mutilating has been done by modern Vandals. The part that is left is not cracked,

but will ring with a clear bell-like tone when struck with a stone or hammer. Sides and end walls are 7 to 8 in. thick. The cover is gone. There is a groove in the box which shows where the cover was formerly slipped into place. There are also shallow holes in the edge of the box, which are believed to be part of the lock.

On the north and south sides of the chamber are two small passages leading to the open air. They are about 8 in. square, and, unlike the larger ones, rise at angles of 33 degrees and 46 degrees. They are believed to be air channels and designed for ventilation only.

Above the King's Chamber are five small chambers. The lower one is called Davison's Chamber and the upper ones Vyse's Chambers, in honor of their discoverers.

It is supposed that they are interstices in the masonry left by the builders, so as to partially relieve the roof of the King's Chamber from the weight of the superimposed masonry.

To the builders of the pyramid the arch was unknown, hence they resorted to this clumsy substitute. What was gained by the first four of these chambers is not very evident to the modern engineer. If they are only intended to serve the purpose of an arch, it would seem that the fifth or last chamber, which is made of long stones leaning together at the top like rafters, might have been placed directly above the King's Chamber as well as in the position it now occupies. The rough and unfinished character of these chambers proves that they do not form a part of the plan of the pyramid, but are simply an accident of construction. These chambers are inaccessible at present.

The Queen's Chamber is 70 ft. below the King's. It is 19 ft. long, 17 ft. wide and 20 ft. high. The roof is pointed and is formed of two sets of stones leaning together at the top like rafters. In the east side is a niche, shaped something like a church window. It is 15 ft. high, 5 ft. wide and originally 3.5 ft. deep. Now it is much deeper, explorers having dug some distance into the back wall in search of treasures.

The Queen's Chamber is also provided with air channels similar to those in the King's Chamber.

In the bottom of one of these air channels was found a small bronze hook and a round stone. It is supposed that some early explorer found the exterior opening and let the hook down with a string to the bottom to see what he might bring up. The round stone was attached to carry the hook down, and both were lost by the breaking of the string.

These are all the passages and chambers yet discovered in the Great Pyramid which were made by the builders. All of the passages, whether for entrance or for ventilation, are inclined to the horizontal at nearly the same angle, and are in nearly the same vertical plane, which plane passes exactly north and south through the pyramid and about 24 ft. east of the middle or apex.

Besides these there are other passages made more recently by explorers, which are simply irregular holes quarried or burrowed through the solid masonry in search of hidden chambers and treasures. They can never be mistaken for the straight, well-lined and polished galleries and chambers made by the builders.

The largest of these forced passages is called "The Well." It begins in the lower end of the Grand Gallery and descends to the vault. Its size is irregular and its course crooked, as if the workmen when excavating it had varied their course from side to side in search of easier digging. It is not known by whom this passage was made. It is now choked with broken stones so as to be entirely inaccessible.

There is another passage called "Al Mamun's Hole," which begins at the middle of the base at the north side of the pyramid and goes in horizontally for about 125 ft.; it then turns sharply around to the east for about 20 ft., and breaks into the descending passage just at the point where the ascending passage begins. It is now partially choked at the exterior with débris so that it cannot be entered, but a perceptible current of air passes through it into the descending passage. It was made by the caliph, Al Mamun, in the eighth century. At that time the true entrance to the pyramid was unknown.

Al Mamun ordered it to be broken up. His workmen began at the base of the pyramid and in the middle of the north side, which point is 60 ft. below and 20 ft. west of the true entrance. After proceeding horizontally 125 ft. towards the center of the pyramid they were on the level with and 20 ft. west of the descending passage. Their mining had so shaken the masonry near them that one of the roof stones of the descending passage fell with a noise loud enough to be heard by the workmen, who immediately turned to the left in the direction of the sound, and after going 20 ft., broke into the descending passage. They then found that the stone which had fallen was the one which had entirely closed up and concealed the entrance to the ascending passage. They also found that this passage was still firmly blocked by a huge granite portcullis, or plug, which entirely

filled it, and that the descending passage was blocked a few feet lower down by a similar portcullis. After vainly attempting to remove these two stones, they found it easier to mine through the masonry around them and break into the passage in their rear. This was done and the two granite blocks still remain in their original position, the explorer now using the excavation made by Al Mamun to get around in their rear.

What Al Mamun found when he did finally arrive in the King's and Queen's chambers is not known. There are the usual Arab tales of gold and gems and enchanted lamps.

One tale is that the splendor of two gems in the King's Chamber made the first five Arabs who entered totally blind, and that finally the caliph had two blind men wrap the two precious stones in thick cloth and carry one of them to the east and the other to the west side of his kingdom. After they were so far separated it was just possible for human eyes to look on their brightness. It is, however, almost certain that the caliph found the chambers much as they are now. They were probably rifled and despoiled much earlier in their history.

It is probable that those unknown explorers who made the mysterious well were earlier than the caliph, and it may be that they carried away the secrets of the Great Pyramid.

Besides these two principal passages there are several shorter ones forced through the original stone work. Col. Howard Vyse broke from the King's Chamber into all five of the smaller ones above. A hole 3 or 4 ft. deep has been dug below the spot where the sarcophagus used to stand, and generally every stone that could be forced out of place, chiseled, broken or defaced has been so treated.

All that part of the descending passage below the entrance to the ascending passage is choked with broken stones, so that it and the vault are now inaccessible.

The material of which the Great Pyramid is built is limestone, quarried near by, and similar to the rock on which it stands.

The galleries and chambers are lined with red granite, and a kind of white limestone quarried at Mokattam on the east bank of the Nile.

The only hieroglyphics ever found about the Great Pyramid were discovered by Col. Howard Vyse in the interior of the construction chambers. Those were made with red ochre on the rough, unfinished sides of the stones, and are supposed to be simply quarry marks for the convenience of the workmen. They were evidently put on with a brush, much as boxes are now

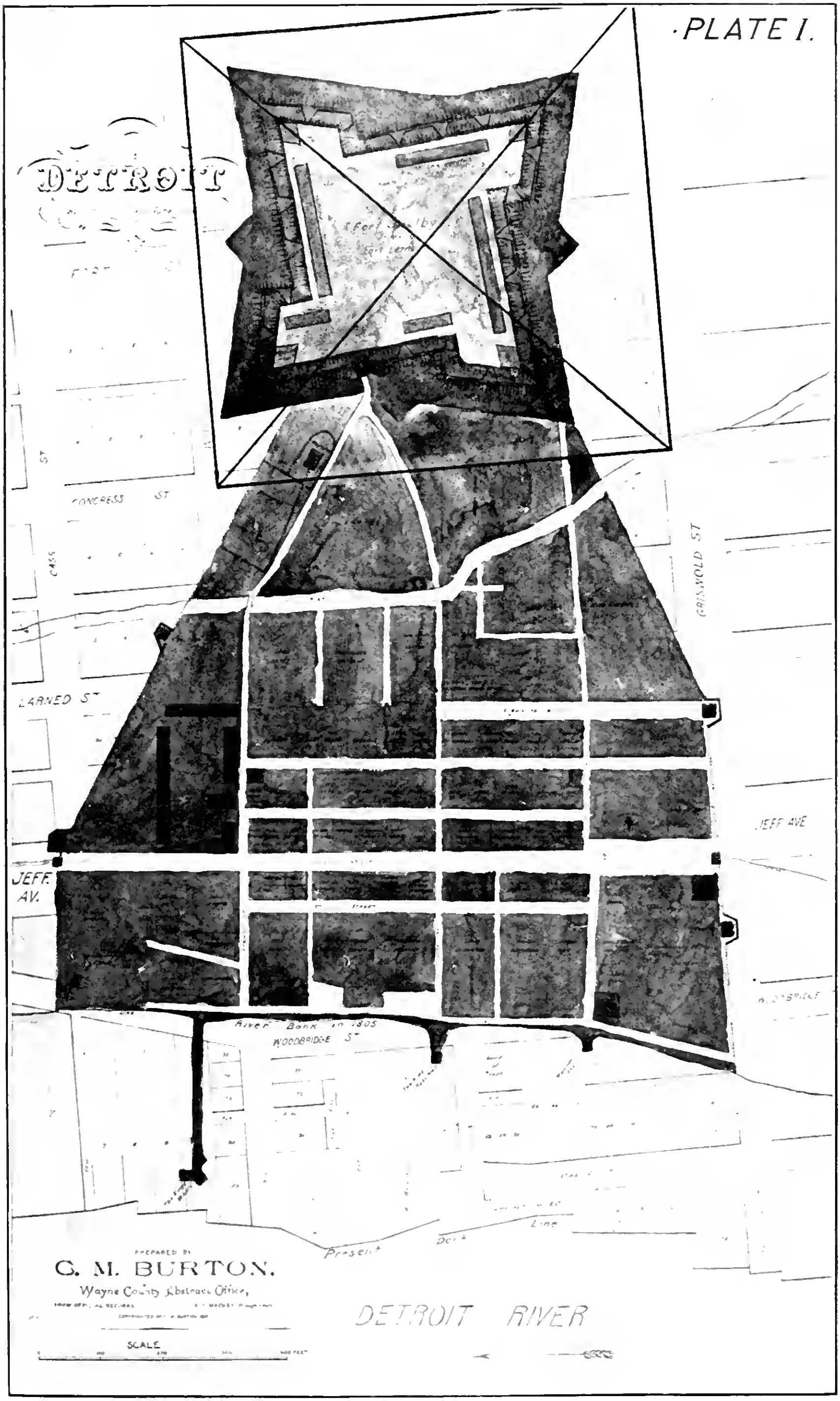
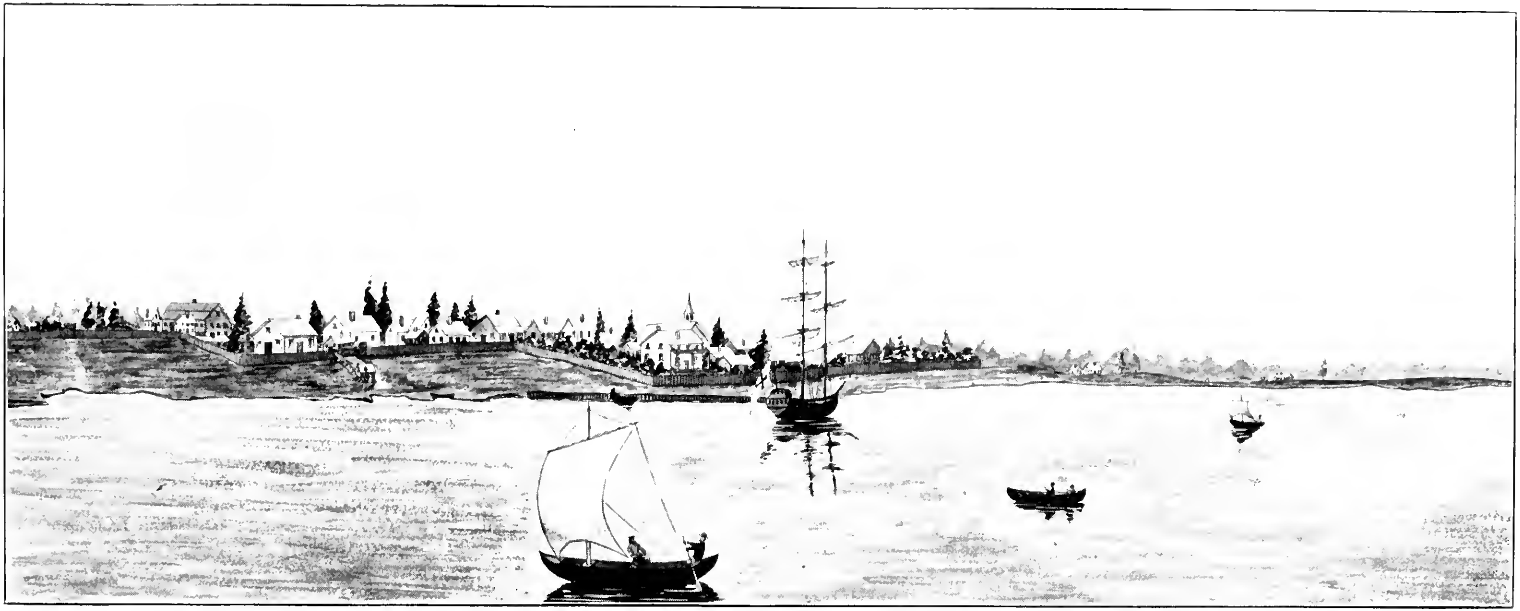
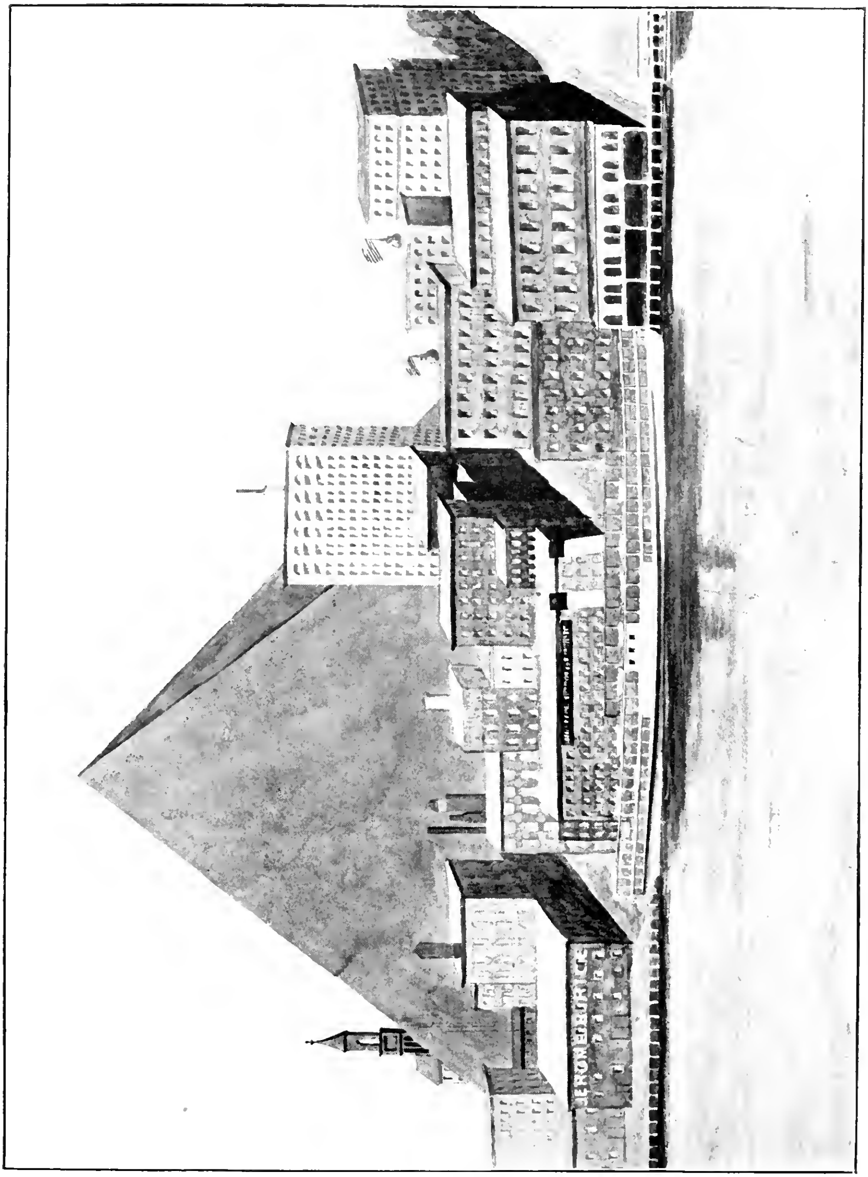


PLATE I.
DETROIT
CONGRESS ST
CASS
LARNED ST
JEFF. AV.
GRISWOLD ST
JEFF AVE
River Bank in 1805
WOODBRIDGE ST
Present Dock Line
PREPARED BY
C. M. BURTON.
Wayne County Abstract Office,
SCALE
DETROIT RIVER

PLATE II.



DETROIT IN 1796.



PYRAMID AS IT WOULD APPEAR IN DETROIT.

marked for transportation. Champollion says that they belong to the earlier hieroglyphics.

It is supposed that the exterior of the Great Pyramid was originally cased, or covered, with Mokattam limestone, similar to that used in lining the galleries and chambers, and that this casing has been stripped off and carried away by the caliphs who ruled Egypt one thousand years ago.

Col. Howard Vyse, in removing the rubbish on the north side, found two of these stones in their original position. One of them has since been placed in the British Museum. Their outer surfaces were highly polished and the joint between them microscopical.

At the corners of the Great Pyramids can be seen shallow excavations in the rock from which the corner casing stones have been removed. Among the débris that surrounds the pyramid can be found many angular fragments of limestone corresponding in shape to the acute and obtuse angles or edges of the existing casing stones. These and many other reasons make it almost certain that the pyramid was originally cased, that its sides were plane and polished, and its top, instead of being truncated as now, terminated in a point. This would make the original dimensions of the pyramid as follows:

Length of side, 760 ft.; height, 485 ft.; area of base, 13.25 acres. At present the length of the sides is 746 ft., the height 454 ft., and the area of the base 12.75 acres.

Such is a general outline of the present condition of the Great Pyramid, with which the Detroit pyramid must exactly correspond.

It is believed by most authorities that all the pyramids were built and used as tombs, probably of kings, and for no other purpose.

There have been many other theories suggested, such as their having been designed for treasure houses, granaries, astronomical and scientific stations, masonic temples, fortifications, etc. But none of these theories is believed to be sustained by appearances, though some have been urged with much ingenuity by their inventors. Some of the most obvious proofs of their being tombs are: they are surrounded by numberless smaller monuments that are known to be sepulchers; hence standing in the midst of a cemetery their location is a strong indication of their use. The stone box in the King's Chamber resembles many of the sarcophagi taken from tombs. All entrance to the interior was permanently closed by the builders, a

thing which would most likely be done if they were tombs, but could hardly be possible if they were intended for any other of the uses ascribed to them. They are found in groups; so also are tombs; but observatories, temples, etc., are usually isolated and single.

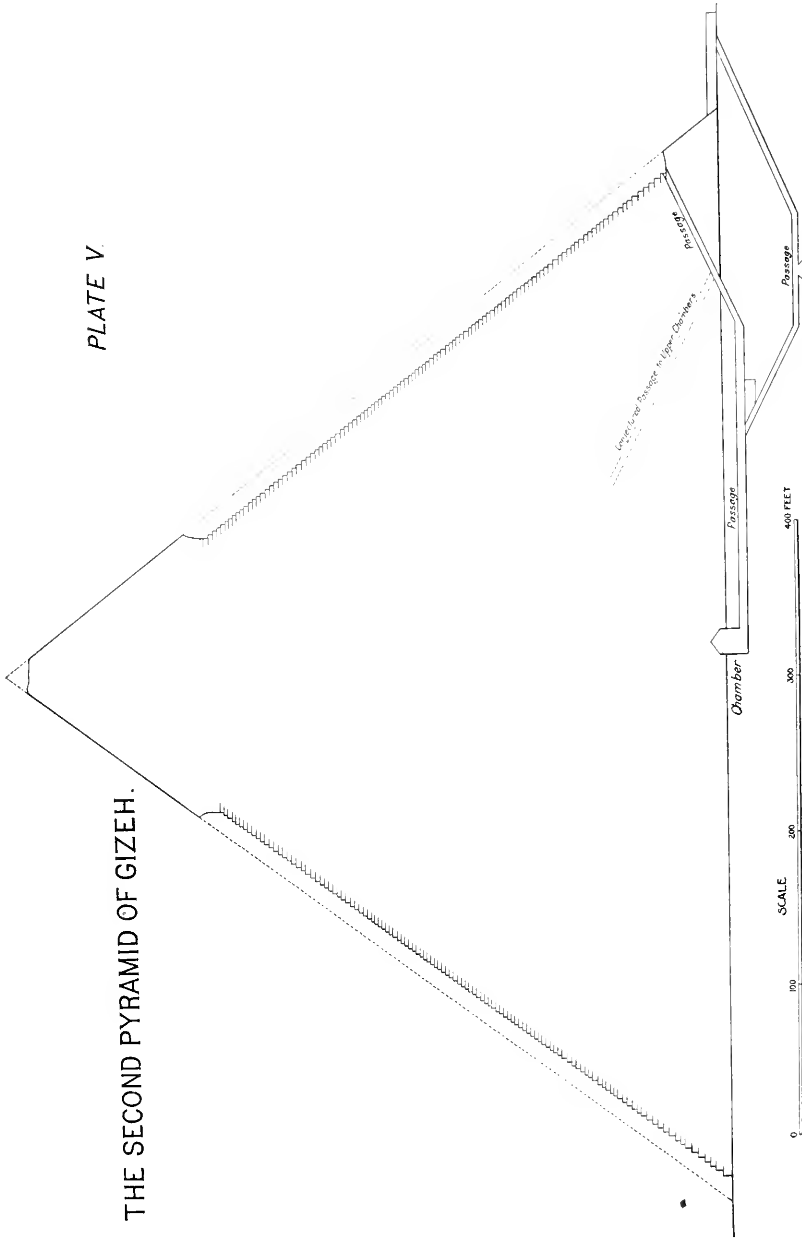
It has been mentioned that there are no graven hieroglyphics on the pyramid. It is true there may have been on the casing stones that have disappeared, but since no trace has been found among the fragments that surround the pyramid, nor on any of the casing stones that still remain, it is probable there never were any. The inscriptions found by Sir Howard Vyse in the construction chambers prove that hieroglyphics were in use at the time of the building.

The age of the pyramids is a question which antiquarians have tried hard to answer. Not less than six thousand years seems now to be the general opinion, while none doubt the possibility nor even the strong probability that they may be much older.

Herodotus makes the first mention of them that is considered at all authentic. He visited them 2 300 years ago and found them much as now, except it is probable that the casing of all of them was entire and the upper system of chambers in the first one unknown.

When Champollion partially succeeded in reading the hieroglyphics, it was hoped that the age of all existing inscribed monuments would become known. But this was not the case. It is true that the relative age of many of them was pretty certainly determined, but the interval of time which separates Egyptian chronology from the Christian era is a matter upon which hieroglyphics give no exact information. It has been thought by some that the angle of inclination, which is common to many of the passages in the first and second pyramids, might have an astronomical significance. For example, the latitude of the pyramids, or the elevation of the pole at that point, is a little less than 30 degrees. The direction of the entrance passage being very nearly north and south, and its angle of elevation a little more than 26 degrees, it is apparent that this passage points to a spot in the heavens about 3.5 degrees below the pole. If the entrance passage had been elevated 3.5 degrees more, so as to point directly to the pole, it would seem probable that the existence of the pole was known to the builders, and that this fact decided the angle of elevation. But since the passage points about 3.5 degrees below the pole it was thought by Sir

PLATE V.



THE SECOND PYRAMID OF GIZEH.

William Herschel that this might have been the place of the lower culmination of the pole star of the period. He, therefore, computed what bright stars had been 3.5 degrees from the pole at different times. His results were not convincing and the problem is yet unsolved. It is possible that the pyramids do yet contain within themselves some clews that will, when found and rightly interpreted, reveal their age.

Are they really wanting, or do they exist and are simply undiscovered? If another Caliph Al Mamun should shake the masonry of the second pyramid about 100 ft. from the entrance, would not another "triangular" stone fall and leave exposed another opening leading to upper chambers and galleries, the same as in the first pyramid?

Professor Smyth discovered and noted that the joints in the floor of the descending passage of the first pyramid were at right angles to the passages, with the exception of two which were marked diagonal. These two were directly under the lower end of the ascending passage. The space in the roof that was once occupied by the stone that Al Mamun's men shook down, also shows that the roof had two diagonal joints as well as the floor.

Professor Smyth attaches a symbolic signification to these joints. It may be, however, and is quite probable that these two stones were the last to be put in place, and were cut wedge shaped, so that they could be forced in from opposite directions, and so make these last joints as close and perfect as the others. But whatever may have been the cause or need for these diagonal joints, it is a fact that they do exist in this one place and nowhere else in the first pyramid.

If the second pyramid has an ascending passage it is possible that similar joints mark the place of entrance.

This description will for the purposes of this paper take the place of the remaining specifications. Before proceeding with the estimates I will speak for a moment of a theory or fancy of my own in connection with the second pyramid. This pyramid stands near the great pyramid, is of about the same size, and in many respects resemdles it. For example, the azimuths of its sides are the same within half a minute, the inclination of the entrance passage is also the same within a few seconds. The geometrical figures of the two pyramids are the same. These points of similarity might lead one to infer other agreements. Plate V shows a section through the middle of the second pyramid. This passage is believed to belong to a small and older

pyramid which has been completely covered by the larger one. It will be noticed that the upper chambers and passages are wanting in the second pyramid.

During February, 1872, I made a visit to the second pyramid to see if there were any indications of an upper series of chambers. At the point where the examination was to be made it was found that the passage was half choked with débris from the exterior, so that the floor could not be seen at all, but the roof could be examined, and in the precise place expected there was found a single diagonal joint. All the other joints in the entire passage were at right angles to the passage. The diagonal joint seemed to have originally been a very fine one, but a settling of the masonry had cracked it open until it was about 1-16 of an inch in width. One small fragment of the stone had been so firmly cemented that it had broken off from one stone and adhered to the opposite one, showing that the original joint could not have exceeded .02 of an inch in thickness.

After making this observation I called upon Mariette Bey, who had charge, under the khedive, of all the excavations in Egypt, and tried to obtain permission to make the necessary examinations in the second pyramid. This was not granted. Mariette Bey at that time was not disposed to let foreigners interfere with a department peculiarly his own. He was especially incensed with Mr. Dixon, who had made his researches and discoveries secretly and in the night time, and had succeeded in carrying away from the country several things which Mariette Bey thought of right belonged to his museum at Boolaque. He, however, listened with interest to the theory of upper chambers, and said he would make the necessary examination when he should again organize a party and take the field for the purpose of making excavations. He also promised to notify me of the time of beginning the work and the results attending it. Nothing has yet been heard from him, and as he has been dead for a considerable time, nothing much is expected.

If a system of upper chambers and galleries should be discovered in the second pyramid, it is barely possible that they may be found undisturbed as they were left by the builders, but it is probable that if found at all, they will be found rifled and despoiled.

The classification of material of the Great Pyramid is very simple. It is built entirely of stone, and but three varieties were used. The great mass of the pyramid, or backing stone, is a coarse limestone, which was quarried from the nearby hills and

was not moved more than a thousand yards. There is 3 313 000 cu. yd. of this material, or about 96 per cent. of the volume of the pyramid. It was quarried or sawed in blocks, having dimensions of from 2 to 13 ft. There were few of the large blocks; 90 per cent. of those that are visible have no dimension greater than 5 ft. They were laid in good quality of mortar. The joints are not close; there are some 3 or 4 in. wide that are filled with broken stone and mortar. The material is about the same as that of the "backing" of the Poe Lock, which was quarried at Drummond's Island.

The outer casing and lining of the passages and Queen's Chamber is a fine-grained limestone, recognized as coming from the quarries at Mokattam on the opposite side of the Nile and about sixteen miles distant. The blocks are generally large, the dimensions ranging from 2 to 10 ft. The most remarkable feature of this part of the work is the fineness of the joints. Most of them are microscopical. The quality of this limestone is about the same as that of the facing stone of the Poe Lock, which was quarried at Kelley's Island. The amount of this stone is approximately 140 000 cu. yd. About 2 000 cu. yd. of granite was used around the King's Chamber. This is recognized as having been quarried at Aswam, about 500 miles up the Nile. The Obelisk in New York is of the same material and was undoubtedly quarried at the same place. The granite work is shown around the King's Chamber, Plate IV. One forming part of the roof or ceiling is the largest known stone in the pyramid; it is 27 ft. long, 6.66 ft. deep, and 5 ft. wide, containing 33 cu. yd. and weighing 77 tons, approximately.

The joints in the sides and roof of the King's Chamber are microscopical. This is a fine red granite, probably not better than Vermont granite.

For the Detroit pyramid there will be needed:

Backing stone, coarse limestone,	3 313 000 cu. yd.
Facing stone, fine limestone,	140 000 cu. yd.
Facing stone, fine granite,	2 000 cu. yd.

The backing stone at the Poe Lock cost $8.50 per cu. yd. The contractor's profits were only fair, and it is believed that this price is a safe and close estimate for the Detroit work. Therefore the backing stone for the Detroit pyramid will cost $28 160-500. The face stone at the Poe Lock cost $28.50 per cu. yd. The only considerable difference between this and the pyramid facing stone is the fine joints in the latter. It is difficult to estimate the cost of making these fine joints, since no work of

this kind has been done near here, or anywhere else so far as I know, in the last six thousand years. It is believed by some that the blocks were ground together. It is known that very fine joints that will even exclude the air can be made by rubbing the stone together. In the absence of any precedent or knowledge whatever, I have assumed that such fine joints would double the cost; therefore the limestone facing is estimated at $57 per cu. yd., or a total cost of $7 980 000.

It is still more difficult to correctly estimate the cost of polished granite in large masses. It is therefore roughly assumed that such granite as is found in the Great Pyramid would cost in Detroit $100 per cu. yd. It happens the amount of granite is relatively small, so that a large error in its estimated cost would make but a small percentage of the total. The amount of the granite being 2 000 cu. yd., its total cost would be $200 000.

Collecting the items, the grand total is as follows:

3 313 000 cu. yd. backing stone @ $8.50,	$28 160 500
140 000 cu. yd. facing stone @ $57.00,	7 980 000
2 000 cu. yd. granite facing @ $100.00,	200 000
Total,	$36 340 500

This estimate does not include cost of site or foundation. The Great Pyramid covers a little more than thirteen acres. I do not know if there is any other thirteen-acre lot in one rectangle on which thirty-six millions of dollars have been expended

Mr. Pool, director of the British Museum, says, " No monument of man's raising elsewhere affords any scale by which to estimate its greatness." Mr. Lewis, professor of architecture, University College, says, " The most gigantic work in the world; one which never has been and perhaps never will be surpassed." Thus far our computations and conclusions have tended to bring out and illustrate the vastness of the structure and its enormous cost. From another point of view it seems small, if not insignificant. Our Secretary has compiled certain statistics concerning the Calumet and Hecla mine. He finds that 19 000 000 cu. yd. of rock have been mined and crushed at a cost of approximately $101 000 000, equivalent to about three pyramids. The loss at the Chicago fire is estimated at $196 000 000, equal to about five pyramids. One of our past presidents is building a tunnel under the Detroit River that is expected to cost $8 000 000, about one fourth of a pyramid; he does not seem to mind it much. Finally, if a day's work is worth a dollar and a half, it

would require 24 000 000 days' work to build a pyramid. The population of the United States is about 80 000 000. It is reckoned that one in five is able to do a day's work; therefore there is available 16 000 000 days' work each day; it would take a day and a half to build a pyramid. If the United States should stop all other work and devote itself entirely to building pyramids, as was probably the case in Egypt, it would, after it got fairly running, be able to turn out two every three days.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by September 1, 1908, for publication in a subsequent number of the JOURNAL.]

DISCUSSION ON PAPER BY PROFESSORS WINSLOW AND PHELPS, "PURIFICATION OF BOSTON SEWAGE: EXPERIMENTAL RESULTS AND PRACTICAL POSSIBILITIES."

(VOL. XL, PAGE 28, JANUARY, 1908.)

MR. M. N. BAKER (*by letter*). — Both interest and value are added to any experimental investigation by conducting it as nearly as possible under everyday working conditions and by applying the small-scale results to a plan embracing large operations. In the paper under discussion we have an account of the experimental treatment, in miniature, of the sewage of a large city, followed by an application of the results obtained to estimates of the cost of treating a large portion of the sewage of the same city. Because a discussion of the possibilities of treating Boston sewage gives concreteness to the experiments, because there would doubtless be some present-day advantage in treating the sewage of Boston, and also because at some future day treatment may be imperative, the presentation of the scheme outlined in this paper is fully warranted. It seems to the writer, however, as though Boston has a dozen sanitary needs which should be met before money is expended on purifying its sewage, particularly if the purification were to be an attempt at disinfection. It seems perfectly safe to assert that dirty pavements cause far more sickness and loss of life in Boston every year than does the pollution of the harbor, while many times more sickness and death are caused there by dirty, disease-infected milk than by unclean streets and polluted tidal waters together.

Quite aside from what purification Boston sewage does or does not need, it is encouraging to learn that there is reason to believe that the sewage of a large American city might be rendered both non-putrefactive and non-infectious by such simple means and at so low a cost. Percolating filters alone may frequently prove sufficient where there is no objection to discharging suspended matter into a river or harbor, provided only the effluent is non-putrefactive. If a low-cost disinfecting agent, applied by simple and inexpensive means, has at last been found, as the authors of the paper believe, many of the sewage purification problems of the future will be greatly altered in character and reduced in cost. As a general proposition, and reasoning from experience in the treatment of both sewage and water by pre-

cipitants and by coagulants, it seems likely that disinfection alone will fail in either bacterial efficiency or in economy, and perhaps in both. In fact, it would not be surprising, if practical experience with the sewage of most cities should show that where the effluents of percolating filters are to be disinfected, intermediate sedimentation would be required.

Mr. G. W. Fuller. — This paper is a distinct addition to the literature in this country upon sewage disposal and brings clearly to the front a gratifying confirmation of a number of the more essential developments which have recently appeared in this field of sanitary work and accentuates several points upon which further data are desirable or necessary.

The distribution of sewage over a filter of coarse stone even under conditions such as will secure efficient aëration, is no longer a feature to be dreaded, although it is clear that there are some details yet to be worked upon. It is gratifying to note that at the testing station of the Institute the authors found no serious difficulties in distribution either with the devices of their own design or with the Columbus nozzle. It seems to the writer that the distribution arrangement at the Albany Street Station has a number of serious handicaps from the standpoint that severe wind storms would likely interfere with its efficiency, whereas with the sprinkler nozzle the action of wind seems to assist materially in the uniform distribution of the spray.

At the small sprinkling filter plant on the Croton watershed at the Montefiore Home it has been found that an accumulation of grease, particluarly upon the front knife edge of the arms supporting the inverted cone, interfered somewhat with the distribution of the spray. It is also found there that the supporting arms must be stiff enough to resist bending, because if they become slightly twisted from the vertical, there is also some interference with the distribution. Taking everything into consideration, it is believed by the writer that the form of nozzle in use at Reading, Pa. (see *Engineering Record*, October 5, 1907), and resembling the first design gotten out for Columbus as stated by Mr. J. H. Gregory in the Trans. Am. Soc. C.E. for December, 1906, is preferable to the design which is generally spoken of as the Columbus nozzle and such as is used at the Albany Street Testing Station.

The writer agrees with the conclusions of the authors that there is no benefit in the operation of sprinkling filters with alternate working and resting periods of considerable length, now that it is assured that successful results may be obtained in

sprinkling filters constructed of stone much coarser than was used in the Columbus tests. The weekly resting periods at Columbus, it should be stated, were advocated with a view to reducing clogging, even at the sacrifice of nitrification, a point which was investigated at length by the writer at Lawrence in 1894, as described in detail in the report for that year of the Massachusetts State Board of Health. With the substitution of the coarser for the finer filtering material in the sprinkling filters the need for the longer resting periods from the Columbus standpoint practically disappears.

The statements in the paper coincide with the views of the writer in regard to the proposition that the septic effluent possesses no advantage due to the septicity which it has undergone. The writer is not prepared to accept, however, the general conclusion that unsettled sewage or unsepticized sewage may be treated as advantageously as sewage which has been clarified and thereby freed of a substantial proportion of its suspended matters and organic contents. It would seem that the Boston results have been obtained with rates and under conditions which do not fully and fairly show the point at issue as regards conclusions to be drawn from filters working side by side under full load. If the statement in the paper were true, it would be hard to reconcile the very striking fact developed in practice that the weak American sewages may be sufficiently filtered at rates materially in excess of those required for strong sewages, particularly those found in Europe.

Some injustice seems to be done coarse-grained filters in this paper according to the views of the writer as regards their hygienic efficiency. It is true that some bacteria will grow at enormous rates not only in septic tanks, but apparently also in sprinkling filters and in the basins in which sprinkling filter effluents are settled. Notwithstanding this, the bacteria entering the purification devices with the original influent are certainly responsive to the laws of subsidence, and it is believed that both in the filter and in the septic tank the removals amount ordinarily to 60 and 75 per cent. of the original bacteria, notwithstanding the fact that sometimes bacterial growths may show the effluent to contain several times as many bacteria as the influent. If our views as to the significance of the antagonism among different species of bacteria as developed in the Chicago Drainage Canal case are sound, then there is little reason to believe that disease germs are to be included among those species which grow within the purification devices in question. Un-

doubtedly there are cases in practice where purification is required to a degree greater than that ordinarily obtained by stone filters. But it appears to the writer that we ought not to draw conclusions to too fine lines from present evidence on this question of hygienic efficiency until the premises are more thoroughly discussed and agreed upon.

The work that is being done by Professors Winslow and Phelps at the Institute Testing Station along bacteriological aspects of these recently developed purification processes is certainly helpful, and it is hoped that they will have time and opportunity to continue their investigations upon points which evidently have not yet assumed their final stand and which give promise to be of much assistance in the future to those communities having sewage disposal problems to solve.

Prof. L. P. Kinnicutt. — I regret that I was unable to be at the meeting of the Sanitary Section at which the paper of C.-E. A. Winslow and Earle B. Phelps on "Purification of Boston Sewage" was presented, for it certainly was a most interesting and instructive paper, and one that had a very decidedly practical bearing; for though it may not be necessary to purify in any way for very many years the sewage of Boston before it is discharged into the harbor, the study that the authors have given to Boston sewage not only points out a method which, when it becomes necessary to treat Boston sewage, affords a comparatively cheap way by which sewage purification can be brought about, but also shows what can be done by cities where bacterial purification as well as the removal of putrescible organic matter is required.

The most interesting part of the paper, it seems to me, however, is the comparison of the work done by percolating filters on septic tank and on thoroughly screened sewage; and for the first time it has been shown that with sewage corresponding in character to Boston sewage, as good an effluent can be obtained from the screened sewage as from the septic tank effluent. This is certainly a decided advance in our knowledge of sewage treatment and may simplify the preliminary treatment of sewage which is to be run on percolating filters. It may even do more than this, for with sewage containing iron sulphate the septic tank action reduces the sulphate to sulphide, and when an effluent contains large amounts of iron sulphide, subsequent treatment is rendered more or less difficult. The rather poor results obtained with the experimental percolating filters at Worcester, I have felt have been at least partly due to the large amount of

iron sulphide in the liquor applied to the beds, and this I think receives confirmation by the results obtained by Winslow and Phelps.

If crude sewage can be run directly upon the percolating beds, all trouble caused by iron sulphide would be prevented. Whether or not the life of a percolating filter will be as long when crude sewage is used, and whether with such use the filter will not be more likely to puddle, can only be determined by further experiments, and by just such experiments as Professors Winslow and Phelps are now carrying on, and the continuation of their work will be watched with great interest.

Mr. G. C. Whipple. — The writer has followed the experiments that have been made at the Sanitary Research Laboratory and Sewage Experiment Station of the Massachusetts Institute of Technology with the greatest interest, as he realizes the value of such studies to the engineering profession. Never before has the sewage problem of Boston been so carefully studied with reference to its purification, and unquestionably when the time comes that some method of purification becomes necessary, the value of the experiments that have been made by Professor Winslow and Professor Phelps and their students and associates will be more thoroughly appreciated even than now.

The writer has little to say by way of discussion of the various topics that have been treated in the present paper. One thing, however, has particularly interested him, namely, the attempt to secure a proper distribution of the sewage by some form of sprinkler. The struggles that have been made thus far indicate that an entirely satisfactory form of sprinkler has not yet been secured. The method of testing the efficiency of sprinklers used by the authors and referred to in this and other papers is ingenious and the results are valuable. Continued study, no doubt, will result in the design of a sprinkler that will do its work properly. The results obtained at this station appear to be better than those which the writer has seen abroad, indicating that progress is being made in this important detail.

Another important feature of the experiment is the attention that has been given to the chemical disinfection of the partially purified effluents. The importance of this feature is becoming more and more apparent.

Not the least valuable of the functions of this experiment station is that of the education of young engineers. Here the students become accustomed to the use of the exact methods of analysis in solving the problems of sewage disposal. As these

students become scattered through the country and come in contact with practical problems, their influence will prove an important factor in the advancement of the art.

The publications on sewage disposal and sewage analysis that have emanated from this experiment station are already becoming numerous, and the writer suggests that it would be convenient for all interested if the authors would prepare a short summary of these various papers and keep a summary up to date by revising it from time to time. There are many engineers who are not interested in the details of the experiments who would be glad to have these general results briefly set forth. A summary of this character is very much needed for the work that has been carried on for so many years at the Massachusetts State Board of Health Experiment Station at Lawrence. Many valuable statistics and discussions are now scattered through nearly a score of volumes. Perhaps it is not too early to make preparations for the publication of such a summary which might be well termed "A Quarter Century of Experiments in Sewage Disposal."

The writer cannot help feeling that in the consideration of these modern schemes for the purification and disposal of sewage there is some danger lest the experience with the older methods be too much overlooked. In sewage disposal, as in other things, there are likely to be decided swings of the pendulum from conservatism to radicalism. Septic tanks and sprinkling filters are useful in their proper places, but they are not always the most desirable or the most economical forms of treatment to be adopted. There may be some danger lest the students in this laboratory become unduly interested in the newer projects. While, naturally, the experiment station must give its chief attention to new and untried methods, it should not neglect the historical and practical side of the subject as exemplified in the many sewage disposal plants already in operation. This, however, is looking at the work from a pedagogical standpoint.

The city of Boston is to be congratulated that such valuable information is being furnished to her without cost, and that there is being trained in her midst a group of men who will be well qualified to handle the problem of sewage purification when by reason of the growth of the city this becomes a necessity.

Mr. R. Winthrop Pratt. — The paper of Messrs. Winslow and Phelps is undoubtedly a most valuable addition to our knowledge of the subject of sewage disposal. The application of the results of the experimental studies to the problem of puri-

fying the sewage from the entire South Metropolitan District is especially interesting.

The problem of disinfection of sewage effluents is one of the most important phases in the work of sewage disposal at the present time. It already serves a valuable purpose in the work of public health officials. As referred to in the paper, the Ohio State Board of Health coöperatively with the United States Department of Agriculture has made somewhat extended investigations into the question of the use of copper sulphate and of chlorine for the disinfection of effluents from sewage works. The data thus secured have already been made use of in connection with the Board's action on proposed projects. The State Health Department of Pennsylvania has also advised or required that provision for disinfection, as a final treatment, be made in at least two cases that have come to the writer's attention.

One of the most important practical applications of the use of chlorine as a disinfectant on a fairly large scale was made last summer under the direction of the State Board of Health at Camp Perry, Ohio. Camp Perry is the new permanent encampment ground and shooting range of the Ohio National Guard, located on the shore of Lake Erie, near Port Clinton. Its construction was commenced last spring, and by August 1 the camp was occupied by two or three thousand men. These included not only the Ohio National Guard, but also rifle teams from the state militias of nearly all the states in the Union and from the United States Army and Navy.

A water supply system with water purification and a sewerage system and sewage disposal plant were provided, although lack of time prevented the entire installation being ready for the troops when they arrived. A main sewer conveyed the sewage from the entire camp to a receiving well, from which it was pumped on to intermittent sand filters having an area of one quarter acre. No preliminary treatment was given except screening and the small amount of settling which incidentally took place in the receiving well. As the treated sewage was discharged into Lake Erie within 600 or 700 ft. of the water supply intake, it was necessary that a high degree of purification be obtained. The sand filters alone, especially at the high rate at which they were operated, could not furnish a safe effluent.

As a finishing treatment, therefore, bleaching powder containing 34 per cent. available chlorine was applied to the effluent. The chemical was so proportioned as to provide for an application of available chlorine at the rate of 7.5 parts per million. The

period of contact of the chemical with the sewage amounted to 5 or 10 minutes. The results showed that the total numbers of bacteria were reduced from several millions to 100 or 200 per cubic centimeter, and most of the samples contained no B. coli. The cost of the bleaching powder was 4 cents a pound, and the cost per 100 000 gal. of sewage treated (which was approximately the average daily flow from the camp) was 75 cents.

MR. GEORGE A. JOHNSON. — The paper by Messrs. Winslow and Phelps on the "Purification of Boston Sewage" is, indeed, a valuable addition to the literature on the subject of sanitary sewage disposal. It is such works as these that advance our comprehensive knowledge of the subject and are doing so much toward lifting the art of sewage disposal from the more or less experimental and indefinite state into the light of practicability and fact.

With regard to the necessity of preparatory treatment of crude sewage before it is applied to sprinkling filters, the writer cannot wholly agree with the conclusions of the authors as set forth in this paper. In his opinion it is clearly erroneous to assume that such filters operate quite as efficiently and economically where crude sewage is applied to them as when sewage is used from which the grosser solids have been removed.

Crude sewage from any community will always contain much paper and other non-nitrogenous matters in particles sufficiently fine to escape a ½-inch bar screen, yet coarse enough to clog a sprinkling filter in a comparatively short space of time. The writer's experience at Columbus, and his close observation of the working of sprinkling filters in England, have satisfied him that the efficiency and operating cost of a sprinkling filter, other things being equal, varies in quite intimate proportion as the completeness of the preparatory treatment of the crude sewage.

Mere screening of sewage does not, ordinarily, cause a very material reduction in the amount of suspended matter (10–15 per cent. with fine screens), while the advantage of sedimentation lies in the fact that from one half to two thirds of the suspended solids are removed in this way, leaving only suspended matter in a finely divided state, which is far less likely to choke the subsidiary filters. A large proportion of these grosser solids are non-nitrogenous, and are only destroyed or comminuted by anaërobic bacterial action, such as does not form a part of the action in an efficient sprinkling filter. These matters, therefore, must accumulate at or near the surface of such filters and there remain until removed by mechanical means.

In the case of Filter B at Columbus, which received sewage which had been screened through $\frac{1}{4}$-inch mesh screens and from which thereafter, in round numbers, 25 per cent. of the suspended solids was removed by sedimentation, surface clogging became so marked after eight months' operation at an average rate of about 2 000 000 gallons per acre daily, that the sewage pooled upon the surface, the quality of the effluent deteriorated because of this surface obstruction, and it became necessary to remove the upper three inches of material from the filter. Other sprinkling filters receiving settled or septic sewage did not call for such treatment during the tests. The filtering material used in this bed was composed of finer particles than that used by the authors ($\frac{1}{2}$ inch to $1\frac{3}{4}$ inches as against $1\frac{1}{2}$ inches to 2 inches), and there is no denying that this fact probably had something to do with the speedy clogging of the filter. The fact, however, that this bed which showed surface clogging received sewage which contained 142 parts per million of suspended matter, and the beds which did not show such clogging received settled sewage containing but 82 and 76 parts per million of suspended matter, respectively, goes a long way toward convincing the writer that his views on this point are in general well founded.

The experience gained with sprinkling filters at the Lawrence Experiment Station is instructive in this connection. Mr. Clark,* in his review of the studies made under his direction, states:

"With filters 10 or 11 ft. deep . . . rates of at least 2 500-000 gallons per acre daily can be maintained and result in good nitrification and an almost invariably non-putrescible effluent. . . . It is possible when sewage has received preliminary treatment, as by sedimentation or septic tanks, to increase this rate materially. At present Filter No. 136, operating at a rate of 4 000 000 gallons per acre daily, and receiving a strong sewage, but one with much of the matter in suspension first removed by sedimentation, is giving a well-nitrified and generally non-putrescible effluent."

English engineers, with the exception of the late Colonel Ducat, are practically unanimous on the necessity of some form of preparatory treatment of crude sewage prior to its application to filters. The writer cannot call to mind one sewage disposal plant of size where crude sewage is applied to sprinkling filters; nor another case where such a procedure has been recommended for adoption in this country.

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* *Engineering News*, April 11, 1907, p. 399.

The authors direct attention to the accumulation of sludge in the septic tank during their experiments, stating that at the end of the first 12 months of operation the depth of the deposit therein amounted to 4 inches, and at the end of 20 months to 12 inches. From published figures the writer estimates that during the first year of operation the Boston septic tank stored about 0.45 cubic yard of sludge per million gallons; during the second year about 0.9 cubic yard per million gallons and during the total period of 22 months about 0.75 cubic yard per million gallons of sewage treated.

Similar results were found in the case of Septic Tank C at Columbus which, in 10.5 months' operation stored about 0.8 cubic yard per million gallons of sewage treated. This tank treated a total of 10 760 000 gallons of sewage which contained on an average of 149 and 43 parts per million of total and mineral suspended matters, respectively, and removed 46 and 49 per cent. of the above matters. It may be well to call attention to the fact that the sewage applied to the tank at Boston contained 135 and 44 parts per million of total and mineral suspended matter, respectively, a practical agreement with the sewage applied to the Columbus tank. The percentage of these matters removed was slightly greater at Columbus.

The writer wishes to point out in this connection that a rate of sludge accumulation in a septic tank not greater than 1.0 cubic yard per million gallons of sewage treated is not high, but decidedly the reverse. When treating the dilute sewages of this country, the volume of sludge requiring removal from a septic tank will ordinarily amount on an average to about 2.0 to 2.5 cubic yards per million gallons of sewage treated. Where such tanks are included in the purification system, and the bulk of the suspended matter is removed from the sewage in this way, the volume of deposit in the final settling basins receiving sprinkling filter effluent usually amounts to about 1.0 cubic yard per million gallons.

There probably exists no definite and fixed relationship between the amount of sludge which will accumulate in a septic tank and any given period of time. Normally one may expect a progressive accumulation during the colder months of the year, and in the spring and summer a period of violent bacterial activity coincident with rapid liquefaction of the sludge which has accumulated during the winter. A variety of factors may upset such a thing as constant accumulation of sludge, important among which are the composition of the sewage and the particu-

lar species of bacteria which it contains. In sewage from a combined system of sewers rain storms will bring down much grit and fine mineral matter which may form an inorganic mat over the sludge in the tank. Subsequent depositions of sludge then are forced to pass through the transitional stages leading to active bacterial liquefaction. If these conditions occur at abnormally frequent intervals, and if at the same time the bacterial flora contain a paucity of such species as are instrumental in the liquefaction of this sludge, the normal septic action may be retarded to a marked degree and the accumulation at the end of the year prove materially greater than in average years.

The authors comment upon the accumulation of a black deposit over the bottom of the sprinkling filter which received septic sewage, a condition not noted in the filter to which crude sewage was applied. A similar deposit was noted in the sprinkling filters at Columbus, but was not restricted to the filters which treated septic sewage, but rather to all of the filters. The conclusion arrived at there, as explaining the reason for this undesirable deposit, was that the underdrainage system was at fault. In filters built with false bottoms, and with drains laid with sufficiently steep slopes, such deposits as these should not occur at the bottom of such filters.

With reference to the bacterial efficiency of sprinkling filters, the authors conclude that the removals obtained at Boston were entirely inadequate. Due consideration does not seem to have been given to the question of growths within the filters, a feature commented upon by the authors, but not in connection with the question of bacterial efficiency. The sprinkling filter is a biological machine and as such is not to be expected to yield an effluent of high bacterial purity, so far as the numbers of bacteria are concerned. Removals of 85 per cent. of the bacteria in the crude sewage, as shown by the authors' experiments are, in the opinion of the writer, far from unsatisfactory for a number of conditions where fairly clear and wholly stable sewage effluents are required, but where effluents of high bacterial purity are not now demanded.

Mr. E. B. Whitman. — I have read the paper on the "Purification of Boston Sewage" with the greatest interest, as I believe the condition of the sewage treated at the sewage experiment station of the Massachusetts Institute of Technology will be quite similar to the condition of the sewage of Baltimore on reaching the disposal works at Back River, about five miles east of the city limits.

The sewage which was treated in Boston on one of the sprinkling filters, and termed "crude sewage," was not, strictly speaking, in a crude state. The "crude sewage" was screened through a half-inch screen, passed through a grit chamber and given some settlement in the distributing tank, to say nothing of the comminuting effect on the solid matter in passing through the pump. The effect of this preliminary treatment was to remove or comminute all the grosser solids, so that the solid matter reaching the sprinkling filter was in a very finely divided state.

The results obtained at Boston by Messrs. Winslow and Phelps confirm the writer's belief that septic action is not necessary previous to the treatment of sewage on sprinkling filters, provided the grosser solids which will clog the sprinkling devices and the filters themselves are removed before reaching the filters. There are several methods by which this removal of the grosser solids can be obtained, such as by means of a septic tank, by preliminary sedimentation for a few hours or by screening. The advantage of the septic tank over those other two methods lies in the fact that a large percentage of sludge which must be handled where sedimentation or screening is used is destroyed in the septic tank.

A recent decision in the United States Circuit Court of Appeals makes it impossible for the septic tank to be used without paying a royalty or having to fight an expensive lawsuit. This decision, however, does admit that sedimentation tanks can be used by the public in sewage treatment, and so brings sedimentation as a preliminary step to filtration prominently to the front among sanitary engineers.

This same decision also states that cesspools are not septic tanks, as there is not a continuous flow of sewage through these cesspools. It occurs to the writer that sedimentation tanks could be used to prepare the sewage for filtration, and these sedimentation tanks be so arranged as to discharge at intervals the accumulated sludge into secondary tanks, which might be termed "sludge digestion tanks." These would not be septic tanks, as the flow through them would be intermittent. There is no doubt about the sludge in cesspools being destroyed in a manner similar to sludge in septic tanks, and by such an arrangement as above suggested the combination of preliminary sedimentation tanks and sludge digestion tanks would accomplish the same results as the septic tanks. It might be possible that the hydrolyses of the solids in the sludge digestion tank would

be inhibited if the contents of this tank became too stale. This could be obviated by arranging the tanks in such a manner that the liquid over the sludge could be changed at more or less frequent intervals which experience might prove to be necessary.

The work of Messrs. Winslow and Phelps at Boston, as well as the writer's recent experience, would seem to demonstrate the possibility of such an arrangement as described above being used to advantage should the decision of the Circuit Court of Appeals be upheld in the Supreme Court and sanitary engineers be thereby shut out from the use of the septic tank or septic action as set forth in the patent papers and allowed by the judges of the Appellate Court.

MR. W. J. DIBDIN. — The very interesting and valuable series of experiments conducted by the authors dealt with an extremely dilute sewage such as is met with in England only under exceptional conditions, the strength being about one third of that of average London sewage. The present method of disposal is the same as formerly obtained for London, i. e., the dispersal of the sewage by dilution in a sufficient bulk of water. This, as at London, will be effective until the degree of maintained aëration is insufficient to allow the full activity of the aërobic organisms which render the sewage matters inoffensive. No nuisance will be observed until the maintained aëration falls below the safety point. In the meantime there is the risk of damage to oyster fisheries and, in regard to the possibility of danger to health through food supply or otherwise, the investigations recorded are not untimely.

The decision that septic and settlement tanks are unnecessary is to be welcomed, as it confirms the theory that aërobic action alone is necessary.

It is stated that the object of the experiments was to obtain a "stable effluent," and not one which complies more or less with arbitrary chemical factors. I would suggest that in testing for this quality the natural conditions should be maintained and the vessel left open to the air instead of being closed after the introduction of the methylene blue, so that the process of absorption of atmospheric oxygen, which takes place in a stream, might continue. Otherwise, if the vessel is closed the conditions of the test are artificial.

The percentage reduction of matters in solution is low for a final process, and the increase in the quantity of suspended matter is not a point for congratulation, although the change in the nature of the matters is of great importance. Since a

pound of living fish is preferable to a pound of fecal matter, the suggestion of the authors that "it is safer to discharge the sludge along with the effluent when it is possible to do so" is more reasonable than a non-biologist might think after perusing and considering only the chemical factors.

In connection with the advisability of treating the effluent with chloride of lime, the authors doubtless did not have in their minds the results of the experience obtained by myself in connection with the deodorization of the sewage of London from 1884 to 1890 pending the opening of the permanent purification works. When I received the order to deodorize the London sewage prior to its discharge into the Thames at Barking Creek and Crossness the only material available in any quantity was chloride of lime. The use of this material produced apparently good results at first, but when the effect of the chlorine disappeared the putrefaction of the sewage matters was objectionable in the highest degree, being worse than the nuisance from untreated sewage. I concluded that we must employ a deodorant which would supply oxygen without acting as a germicide. Permanganates were used, and in order to obtain a sufficient supply, I manufactured it by thousands of tons at Crossness on behalf of the Metropolitan Board of Works. The nuisance disappeared, in consequence of the oxidizing action of the permanganate, which also allowed the aërobic organisms to purify the river while precluding the putrefactive anaërobic action which followed the use of chloride of lime. Of course my action was resented by the bleach industry, and its foremost representatives argued that the oxidizing power of bleach was greater than that of permanganate for the money expended. The matter was referred to Sir Henry Roscoe, who confirmed my investigations after another £10 000 had been wasted on chloride of lime and the river had been made abominable once more by the use of that material.

There is a special point in connection with the Boston sewage which must not be overlooked. Since the dead matters of the sewage are turned into living matters by the use of the trickling filters and the sewage is thereby rendered self-purifying as long as sufficient aëration is maintained, the action of the chloride of lime will be to undo much of the work effected by the filters by turning the living into dead matter. The work thus undone will be repeated in the harbor, just as at present the original dead matters are rendered live and self-purifying. One wonders, therefore, if the chloride is to be used, what is the good of first treating the sewage on filters.

Of course where there are special pathological reasons for disinfection, and the bulk of sewage is small in comparison with the diluent water into which it is discharged, the use of chloride is comprehensible. In such a case, however, the chloride may be added to the sewage direct and the cost of filters saved, since the work of the filters will be carried out efficiently by the aërobic organisms in the diluent water when the effect of the chlorine has passed off.

Where the effluent is fairly free from "suspended" matters, it may be advisable to treat with chloride of lime, since the amount of living "animal" matters then killed will be small.

The following comparison of the results of the treatment of Boston sewage on trickling filters with those obtained by treating the sewage of High Wycombe in England on slate beds may be of interest. The accompanying tables show how closely the two sewages compare. The data for the High Wycombe results are from independent analyses made for the local authority of which I had no knowledge until I received a copy of the official report.

The chief difference between the two sewages is in the oxygen factor, presumably in consequence of the different methods of conducting the determinations. The results for the High Wycombe samples were obtained with the permanganate acting at 27 degrees cent. for 4 hours. I presume the Boston results were obtained in the manner described in the report of the Massachusetts investigations from 1888 to 1890, page 722, i. e., at boiling point for two minutes.* Otherwise the sewages are closely comparable if the albuminoid ammonia in the High Wycombe analysis is doubled to make it analogous to the nitrogen found by the Kjeldahl method as described on page 711 of the same report.

The effluents differs essentially in respect of suspended matter. The Boston effluent shows an increase from 9.4 to 9.7 grains per gallon, whereas the High Wycombe effluent shows a reduction from 10.2 to 3.6 grains. The reduction of organic nitrogen in the Boston effluent was 47 per cent., against a reduction of 46 per cent. of albuminoid ammonia for High Wycombe. The incubation test in both cases gave no fermentative change. The conclusion to which I am forced is that treatment of Boston sewage on slate beds *similar to those at High Wycombe* would give better results than those obtained by the use of trickling filters.

The number of acres of beds, 8 ft. deep, would be 23, against 50 required for trickling filters, as the number of gallons daily

* Thirty minutes. — C.-E. A. W.

treated per cubic yard of bed was only 155 for trickling filters at Boston against 336 on slate beds at High Wycombe.

The experiments made by the authors of this paper and described by them in a previous report on brick beds bear little relation to slate beds. The use of small bricks 1½ by 4 by 12 in. would obviously give a different medium from thin slate layers, each slate varying from 1 to 2 sq. ft. super and averaging ¼ in. in thickness. The retention of solids, to take one point alone, is greater where the unit of surface is greater, as the solids tend to break away at the edges of the surfaces as the gelatinous organic condition progresses.

From results obtained at Devizes with a stronger sewage, I am inclined to think that the High Wycombe beds would treat a far larger volume of this dilute sewage daily and would still give satisfactory results. I have therefore suggested that one of the two beds at High Wycombe should be worked at six fillings daily, while the other remains at three. The estimate of work implied in this is really a low one in consequence of the manner in which the humus resulting from the sewage suspended matters is "worked over," to use the authors' phrase, and escapes from the slate layers and so obviates the risk of undue accumulation.

The deposit on the slate abounds in worms and the usual infusoria are plentiful. Although the bacteria are important it was in view of the higher organisms that I called the action "biological" originally in 1892. The term "bacteria beds," however, became popular. The higher organisms are employed to the maximum advantage in the thin layers of "living earth" obtaining on the slates and hence the results above described are explicable.

Boston and High Wycombe Sewages.
Comparative Results.

Grains per Gallon.	Sewage.		Effluents.		Average London Sewage.
	Boston.	High Wycombe.	Boston.	High Wycombe.	
Total suspended matters,	9.4	10.22	9.7	3.64	30.6
Organic nitrogen (Kjeldahl) in solution,	0.4*	——	0.22*	——	——
Albuminoid NH_3,	——	0.150	——	0.082	0.386
Free NH_3,	0.98	1.050	0.73	1.070	2.995
Oxygen consumed in solution.	3.61‡	0.481†	1.75‡	0.342†	3.416†

* To be reduced to half these figures to equal albuminoid NH_3.
† At 4 hr. at 80° fahr.
‡ At boiling point for 30 min.

PERCENTAGE REDUCTION OF CONSTITUENTS IN EFFLUENTS.

	Boston Sewage.	High Wycombe Sewage treated on Slate Beds.
Organic nitrogen,	47.0%	......
Albuminoid NH_3,	......	46.0%
Oxygen consumed in solution,	42.0%	29.0%
Suspended solids,	Increased by 9.0%	Decreased by 62.0%
Incubation test,	No fermentative change	No fermentative change
Appearance,	Turbid	Cloudy.

NUMBER OF GALLONS TREATED PER CUBIC YARD OF BED DAILY.

Boston	High Wycombe.
155	336

NUMBER OF ACRES OF BEDS REQUIRED TO TREAT BOSTON SEWAGE BY TWO METHODS. 8 FT. DEEP.

As suggested.	On slate beds.
50	23

[Quantities have been expressed here by the British Imperial gallon. SECRETARY.]

PROF. C.-E. A. WINSLOW. — The authors of the paper on "The Purification of Boston Sewage" feel gratified that its discussion has elicited such important contributions to the question of sewage disposal. Nothing is of greater moment at the present time than to secure a general exchange of opinion between men of wide experience. A comparison of the opinions expressed makes it possible to determine pretty accurately what definite conclusions have been reached as a result of the work of the last two or three years and what questions are still in active dispute and awaiting a final settlement.

In the first place, there seems general agreement to-day that the anaërobic stage in sewage treatment is undesirable in so far as it affects the liquid sewage itself. The septic tank is a mechanism for removing solids by sedimentation and liquefying as much as possible of the sludge removed. Its action on the liquid should be minimized as far as possible. This means, of course, that septic tanks should be designed to secure the maximum removal of suspended solids by sedimentation with the least possible prolongation of the period of treatment. The second point, which may be regarded as settled, is the contention that the operation of the trickling filter should be made as uniform as possible. A bacterial bed is a biological mechanism, the operation of which should be made as constant and even as possible. Of course, intermittent dosing at intervals of a few

minutes, does not essentially alter the conditions in the bed, but it seems now accepted that long resting periods for trickling beds are to be deprecated.

On the other hand, several of the questions raised in the paper under discussion are still open ones. The first and most important point, perhaps, concerns the possibility of treating crude sewage in biological beds, wholly or mainly aërobic in nature, without preliminary removal of solids. The position of the authors is that this is at times good policy. Mr. Dibdin and Professor Kinnicutt appear to hold the same view, while Messrs. Fuller and Johnson dissent from it. It is undoubtedly true, as Mr. Fuller says, that if crude sewage can be purified at a given rate, septic sewage may probably be purified at a somewhat higher rate. It is true, too, as Mr. Johnson points out, that if crude sewage can be treated on a bed built of material of a certain size, septic sewage can almost certainly be treated on a bed of finer material. In our particular case, however, it was evident that crude sewage could be treated at a rate of 2 000 000 gal. per acre per day on a bed of $1\frac{1}{2}$-inch to 2-inch stone with success. Mr. Whitman's criticism of the character of the sewage applied is apparently made under a misapprehension. The material settled out in the distributing tank was never removed and all passed eventually to the filters. The half-inch screen and grit chamber removed only the heavy, inorganic material, as shown by the fact that it was spread out on the experiment station grounds in the midst of a city without production of odor. Such material as this will, of course, be removed in any practical process, as it would be the worst economy to allow a septic tank to sludge up with street washing and grit.

We are, of course, very far from wishing to extend our conclusion to all other cases, or to many other cases. There are two main objects to be attained in sewage purification,— the removal of suspended solids and the oxidation of organic matter. Solids may be removed before treatment in filters, or after treatment in filters, or they may be allowed to accumulate in the filter beds. Experience shows that the last policy is rarely economical. Which of the first two shall be chosen depends on various peculiarities of the individual case. Where trickling beds are used, however, if an effluent free from suspended solids is desired, some final sedimentation will generally be required. If this is the case, it must often be of advantage to dispense with the preliminary sedimentation, purifying the crude sewage on trickling beds and doing all the necessary removal of solids at the end of

the process. In any given case this may or may not be cheaper than preliminary septic treatment combined with subsequent sedimentation. Our own contention is that it is possible to purify crude sewage on trickling beds, and that under certain circumstances it is better practice to do so. It seems to be so in the Boston case.

A second question of considerable interest is raised by Mr. Dibdin's comparison between the trickling bed and the contact bed. It is interesting to notice that the general effect of the two processes is so nearly the same. The incubation test, however, cannot of course be compared, since, as Mr. Dibdin points out, the test used by us was a very severe one. The main difference, aside from the high rate obtained by the use of contact beds at High Wycombe, lies in the fact that the contact beds removed two thirds of the suspended solids present, while our trickling beds slightly increased the suspended matter. This, in my judgment, indicates a distinct advantage for the trickling bed. Any biological bed which removes suspended solids must store a considerable portion of them. Storage of suspended solids means limitation of the life of the bed and its ultimate renewal. Of course Mr. Dibdin's plate beds, with their large capacity, minimize this danger as far as possible, but the fact that the trickling bed does not store suspended solids at all seems to promise an almost indefinite extension of its activity. In my own opinion, some anaërobic process furnishes the best means of removing solid material if it must be removed, and this can, I think, be done with greatest economy apart from the purification process itself, either preceding or following it.

The third point upon which we are not all in agreement is the question of the efficiency of trickling beds with regard to bacterial purification. There is no doubt of the fact that septic tanks and trickling beds ordinarily effect, as Mr. Fuller says, a purification of 65 to 70 per cent. on the original bacteria entering the system. It is also, no doubt, true that disease germs do not grow in trickling beds. Neither probably do colon bacilli, but colon bacilli persist, according to authentic results, at many plants, in about the same proportion as the other bacteria applied and appear in the effluent in numbers perhaps a quarter or a third as great as those in which they occur in the sewage. If this is the case, we have no right to assume that the removal of disease germs is any better; and it certainly cannot be considered that bacterial purification of 75 per cent. is of any particular sanitary consequence. Of course, in many cases bacterial purifi-

cation of sewage is entirely unnecessary, but I am strongly of the opinion that, where it is necessary, septic tanks, contact beds, and trickling filters cannot be relied upon.

Where special bacterial purification is desired, the experience of the last two years has clearly shown that it can be accomplished by disinfection with some form of chlorine. No other disinfectant appears to approach chlorine in economy and efficiency. There still seems, however, to be considerable difference of opinion in regard to the exact cost of this procedure. In Mr. Pratt's very interesting account of the disinfection of the sewage at Camp Perry, Ohio, he gives the cost of the process as $7.50 per million gallons. Our estimates were $1.50 for Boston trickling effluent. This is fairly typical of the differences which appear between different estimates in regard to this process. In the particular case in question the high cost at Camp Perry appears to be due to two things. In the first place, the chemical was applied at the rates of 7.5 parts of available chlorine per million. In our own case we have found 5 parts amply sufficient to disinfect trickling effluent, and sand effluent can be treated with a much smaller amount. In the second place, the price quoted by Mr. Pratt is 4 cents a pound. This was presumably due to peculiar local conditions. The market price of this product is quoted at about 1¼ cents per pound, and with the addition of freight charges it has been obtained in small quantities below 2 cts. in recent experiments at Red Bank, N. J., and Baltimore, Md.

We are in entire agreement with Mr. Dibdin's contention that the disinfection of putrescible sewage is generally an undesirable thing. His experiments on the treatment of the Thames water with chloride of lime taught on a large scale the lesson that putrescible matter must eventually putrefy, and that to delay the process by using a disinfectant only makes the ultimate event worse. Our point of view is that when stability has been attained, that is, when there is no longer any danger of putrescibility and no longer any need for oxidizing bacteria, it is safe and proper to remove the disease germs by disinfection. Organic stability must be attained as the primary end and by bacterial means. After that is done there can be no harm in removing the germs from an effluent containing only stable humus-like solids. The disinfectant is, of course, used up in the process, so that no damage will be done to the living organisms in the water into which the end product is discharged. We entirely agree with Mr. Dibdin and with Mr. Baker that the disinfection of crude

sewage is only justifiable under exceptional conditions of great dilution.

In closing this discussion I want to take the opportunity of expressing again the desire of the staff of the Sanitary Research Laboratory and Sewage Experiment Station of the Institute of Technology to be of assistance in the study of the scientific and engineering problems which come within its scope. We are ready at any time to attack, as far as we are able, problems of fundamental and general interest which sewage engineers care to submit to us. That is one of the objects for which the station exists, and we shall always be glad to pursue such investigations as far as time permits.

DISCUSSION ON MR. HARPER'S PAPER, THE SAN FRANCISCO EARTHQUAKE OF APRIL 18, 1906.

(Vol. XL, page 87, February, 1908.)

MR. LUIS MATAMOROS, San José, Costa Rica, April 1, 1908. — In Mr. Harper's paper on the San Francisco earthquake I have read the only clear conception about the direction of the seismic movements which accords with my own studies of the theory of the cause of earthquakes, published a few years ago, at the time of the destruction of the city of St. Pierre (Martinique).

On or about those days, June, 1902, the *Scientific American* in New York, and *Nature* in Paris, expatiated upon some new theories about earthquakes which I esteemed wrong, and to prove such an assertion published in *Boletin de las Escuelas*, San José de Costa Rica, on the 12th of July, 1902, my own conclusions, after many years of experience and observation. In that paper I tried to prove:

First. That the figure of the earth is not a constant one.

Second. That the continual changing of form generates a great amount of heat and electricity.

Third. That this heat is the "internal heat" of the earth, and not the "central fire," as was thought before.

Fourth. That the great amount of electricity developed by the friction of the molecules of the earth in changing its form accumulates in certain points of the globe, and when its potentiality becomes high is discharged through weaker points, causing the earthquake.

Fifth. That this theory is the only one which explains clearly its observed effects on monuments and buildings, and also explains the phenomena of the zones into which the earth is divided, a fact in accord with experience and observations.

To prove that the figure of the earth is not a constant one is very easy. Mr. Mansfield Merriman, in his splendid work on the "Figure of the Earth," Chapter V, says: "The word *geoid* is used to designate the actual figure of the surface of the waters of the earth. The sphere, the spheroid, the ellipsoid, the ovaloid and many other geometrical figures may be, to a less or greater degree, sufficient practical approximations to the geoidal or earthlike shape, yet no such assumed form can be found to represent it with precision. The geoid, then, is an irregular

figure peculiar to our planet, — so irregular, indeed, that some have irreverently likened it unto a potato, —and yet a figure whose form may be said to be subject to fixed physical laws if only the fundamental ideas implied in the name be first clearly and mathematically defined." In the last paragraph of the book we read, " In conclusion it will be well to note that our geoid is not a fixed and constant figure."

Mr. Harper is not mistaken in his apprehension of the movements as he explains them. His judgment is also correct when he apprehends the direction of the movements and the time in which they occur. He has nothing to do but to consider the least-work of an electric spark crossing the mass of the earth. When the sparks cross the space it is well known that the figure of the path for least-work is a " Cartesian folium " : practically you call this figure a zigzag, because we cannot see the curve, but it is very easy to explain it as a logical fact.

If we imagine an electric spark in the air in an indefinite direction, when it runs the pressure of the air becomes higher, resisting the motion. The spark rarefying the air reaches a point where the air's resistance is greater than its power, and the spark, then, comes back traversing with much less effort than at the beginning the air already rarefied, continuing on this back and forth movement until its energy is consumed, making practically a zigzag.

The mechanical effects of this kind of movement are the same as a pair of forces acting in contrary directions; coupling forces acting upon a body give a movement of rotation around the center of the body, as we feel at the instant of the earthquake, which Mr. Harper has confirmed by his own observation in the *cemeteries*.

In my paper I said: " Yet we have vestiges in the *cemetery* of this city and on the square columns of the barracks of the city of Alajuela which show the phenomena of the rotation produced by earthquakes."

I will end here, but not before offering my compliments to Mr. Harper for his very valuable work.

ASSOCIATION

OF

ENGINEERING SOCIETIES.

VOL. XL. **JANUARY, 1908.** No. 1.

PROCEEDINGS.

Montana Society of Engineers.

BUTTE, MONT., DECEMBER 14, 1907. — The meeting of the Society for December was held at 225 North Main Street, Room No. 16, at the usual time. Quorum present. Ex-President C. W. Goodale presided. The minutes of the last meeting were read and approved. The application for membership of Edward D. Kinney was read, approved and the ballot ordered in the regular manner. The Secretary read an outline of the program of the Annual Meeting, also a letter asking the Society to take some action towards the suspension of Annual Assessment work on Mining Claims for 1907. After discussion it was decided that the time was too short to consult Montana's Congressmen in the matter. The Secretary reported the death of Mr. Chas. A. Molson, a member of the Society, and Messrs. Dunshee, Moore and Adams were chosen as a committee to draft resolutions.

The committee appointed at the last meeting reported the following amendment to the By-Laws, to be voted on at the next meeting.

Section 8, Article V. In case of failure on the part of any member, for three years to pay the prescribed annual dues, or any special assessments that may have been levied, after due notice of such delinquency shall have been given by the Secretary, the Society may, at any regular meeting, by a two-thirds vote of the active and associate members present and voting, declare such delinquent member indefinitely suspended or expelled from the Society; provided that the dues and assessments of any member may, for cause shown, be remitted by an affirmative two-thirds vote of the active and associate members at a regular meeting.

Following is an alternative amendment to Section 8, Article V: In case of failure on the part of any member for two years to pay the prescribed annual dues or any special assessments that may have been levied, after due notice shall have been given by the Secretary, the name of such delinquent member shall be dropped from the list of members of the Society, and if such delinquency shall continue for three years, such delinquent member shall forfeit all rights to membership and shall not be reinstated without being re-elected and paying the same initiation fee and annual dues and assessments demanded from other candidates for admission.

Respectfully submitted,

JOHN D. POPE.

Mr. C. W. Goodale gave an interesting talk about several irrigation projects in northern Montana, which he had visited during the past season.

Adjournment.

CLINTON H. MOORE, *Secretary.*

Technical Society of the Pacific Coast.

San Francisco, December 13, 1907. — A meeting of the Society was held on Friday, December 13.

The meeting was called to order by Past President Marsden Manson.

The Secretary read the minutes of the last regular meeting, which was held on December 6, in Coopers Medical Hall. At this meeting a reception was held in honor of Past President George W. Dickie, who had been absent from the state for about eighteen months and who returned to reëstablish his home in California. Mr. Dickie addressed the members present and referred to the pleasant relations existing for many years between the Technical Society and the older members, expressing the hope that these relations, which had been severed by the great catastrophe, may be renewed within the immediate future.

Mr. Axel Welin, member of the Naval Institute of Architects, delivered a lecture on the subject of "Appliances for Manipulating Life-Boats on Sea-going Vessels." The lecturer described in detail the design of a davit for sea-going vessels which had been applied successfully by the great traffic companies of the Atlantic.

The minutes of this meeting were approved.

The following Nominating Committee was appointed to select a ticket of officers for the ensuing year: Marsden Manson, Jas. C. Bennett, Loren E. Hunt, John B. Leonard, Frank P. Medina.

A ticket is to be prepared by this committee, which will be voted in time to announce the result at the annual meeting to be held in the middle of January, 1908.

The Board of Directors discussed the advisability of holding the regular meetings at some restaurant, preceding the ordinary course of business by an informal dinner. The difficulty of getting the scattered members together in San Francisco at the present time is so great that unless the meeting be combined with the usual evening meal it will not be well attended.

The Secretary was instructed to make the necessary inquiries and arrangements so that the annual meeting, which is to be held in the middle of January, may be held at one of the down-town restaurants.

The meeting thereupon adjourned.

Otto von Geldern, *Secretary.*

ASSOCIATION
OF
ENGINEERING SOCIETIES.

VOL. XL. FEBRUARY, 1908. No. 2.

PROCEEDINGS.

Engineers' Club of St. Louis.

ST. LOUIS, DECEMBER 4, 1907. — The 642d meeting of the Engineers' Club of St. Louis was held at the Club rooms, 3817 Olive Street, Wednesday evening, December 4, 1907, at 8.15 o'clock. President Fish presided. Nineteen members were present.

The minutes of the 641st meeting were read and approved. The minutes of the 431st and of the 432d meetings of the Executive Committee were read.

The following applications were read: Hendrich, Walter F. (member); Quebbeman, Edward (associate member).

The Secretary read a letter from Mr. W. R. Bascome announcing the donation to the Club of the revised drawings and specifications for the Manhattan Bridge of New York City. The Secretary was instructed to make due acknowledgment of the same.

Mr. E. R. Fish read the report of the Executive Committee for the year 1907. On motion duly seconded it was voted that the report be received and filed.

Mr. A. S. Langsdorf presented a report of the Secretary's office for 1907. It was voted that the report be received and filed.

The report of the Librarian for 1907 was presented by Mr. A. S. Langsdorf. It was voted that the report be received and that it be referred to the incoming Executive Committee for consideration.

Mr. E. E. Wall presented the Treasurer's report for 1907. It was voted that the report be received and referred to the Executive Committee for action.

The report of the Entertainment Committee for the year 1907 was presented by Mr. A. S. Langsdorf. It was voted that the report be received and filed.

The report of the Board of Managers of the Association of Engineering Societies was read by Mr. A. P. Greensfelder. It was voted that the report be received and filed.

Inasmuch as the membership of the Club is now in excess of two hundred and fifty, the Club is entitled to three representatives on the Board of Managers. The Nominating Committee, through Mr. E. B. Fay, therefore presented a supplementary report, nominating Mr. J. T. Dodds as the third member of the Board of Managers for the year 1908. The following two members had been nominated for the Board in the original report of the Nominating Committee: Mr. R. L. Murphy and Mr. O. W. Childs.

The President called for additional nominations for officers for the year 1908, but none were made.

Mr. William H. Bryan announced the election of Mr. M. L. Holman as president of the American Society of Mechanical Engineers. After some discussion it was moved to tender a complimentary dinner to Mr. Holman and to refer the details to the incoming Executive Committee. Motion carried.

It was moved and seconded to hold the usual annual dinner, all details to be arranged by the present Executive Committee. Motion carried.

Adjourned.

A. S. Langsdorf, *Secretary.*

Annual Dinner.

St. Louis, December 18, 1907. — The 643d meeting of the Engineers' Club of St. Louis was held at the Mercantile Club, 7th and Locust streets, on Wednesday evening, December 18, 1907, at 7.30 o'clock, President Fish presiding. The total attendance was 46, of which 40 were members and 6 were guests. Among the latter were Prof. Benjamin F. Groat of the University of Minnesota, Prof. C. M. Woodward of Washington University, and Mr. Daniel N. Kirby of St. Louis.

The results of the letter ballot for the election of officers for 1908 were announced as follows:

President — W. G. Brenneke.
Vice-President — E. E. Wall.
Secretary and Librarian — A. S. Langsdorf.
Treasurer — O. F. Harting.
Directors — J. F. Hinckley, W. V. N. Powelson.
Board of Managers — R. L. Murphy, O. W. Childs, J. T. Dodds.

After a course dinner the following toasts were responded to: Address of the retiring president, " Our Sphere of Influence," E. R. Fish; " An Engineering Problem," Prof. B. F. Groat; " What is there in It for Us? " E. E. Wall; " A Legal Aspect of Engineering Responsibility," D. N. Kirby; " Elasticity as a Desirable Quantity of Engineering Specifications," W. Robbins.

At the conclusion of the regular addresses, Professor Woodward was called on for a few remarks and responded informally.

The meeting adjourned at 11 p.m.

A. S. Langsdorf, *Secretary.*

St. Louis, January 15, 1908. — The 644th meeting of the Engineers' Club of St. Louis was held at the Club rooms, 3817 Olive Street, Wednesday evening, January 15, 1908, at 8.15 o'clock, President Brenneke in the chair. There were present 41 members and 15 visitors.

The minutes of the 642d and 643d meetings were read and approved.

The minutes of the 433d and 434th meetings of the Executive Committee were read.

The following were elected: Walter F. Hendrich (member); Edward Quebbeman (associate member).

Applications were read from Donald G. Scott (member), Benjamin McKeen (member), Walter E. Bryan . (junior).

The Secretary announced the appointment of the Entertainment and Membership committees as follows:

Entertainment Committee: C. A. Bulkeley, chairman; A. I. Jacobs, W. H. Hand, R. K. Einstein, R. H. Phillips.

Membership Committee: A. C. Cunningham, chairman; R. L. Murphy, R. Morey.

Mr. H. Struckmann then presented the paper of the evening on "The Development of the Portland Cement Industry in Europe and the United States." The history of the manufacture of cement was briefly reviewed, and the remarkable growth of the industry shown by comparative figures since the year 1890. Lantern slides were used freely to show various processes of manufacture in the United States and abroad, and samples of the material were shown in all stages, from the raw state to the finished product.

At the conclusion of the address a lively discussion was participated in by a large number of those present.

Adjourned.

A. S. LANGSDORF, *Secretary.*

Boston Society of Civil Engineers.

BOSTON, JANUARY 22, 1908. — A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 8 o'clock P.M., President E. W. Howe in the chair; one hundred and fifteen members and visitors present.

The record of the last meeting was read and approved.

Messrs. William H. Balch, Thomas F. Campbell, Albion M. Deane, Walter J. Grady, Angus B. MacMillan and Arthur D. Weston were elected members of the Society.

On motion of Mr. A. H. French, the President was requested to appoint a committee of three to retire and report to the meeting the names of five members to serve as a committee to nominate officers for the ensuing year. The President named as that committee, Messrs. A. H. French, R. A. Hale and J. A. Gould. This committee reported the following names for members of the nominating committee, Arthur L. Plimpton, Leonard C. Wason, John L. Howard, Henry B. Wood and Charles W. Sherman. On motion of Mr. F. P. Stearns, the report was accepted and the members named were chosen as the nominating committee.

On motion of Mr. FitzGerald, it was voted to hold the customary annual dinner and that the usual committee (Mr. Henry Manley) be appointed to make the necessary arrangements.

The literary exercises of the evening consisted of a description of the Double Track Railroad Tunnel under the Detroit River at Detroit. Mr. H. A. Carson gave an historical account of various methods which had been used for the construction of similar tunnels and described plans which had been suggested for the building of this tunnel, illustrating his remarks by the aid of lantern slides. Mr. William J. Wilgus, of New York, Chairman of the Advisory Board of Engineers, was then introduced and gave a most

interesting account of the plan finally adopted for the Detroit Tunnel and of the work of construction now in progress. A large number of views were thrown on the screen showing various stages of the work.

On motion of Mr. F. P. Stearns, the thanks of the Society were voted to Mr. Wilgus for his kindness.

Adjourned.

S. E. Tinkham, *Secretary.*

Montana Society of Engineers.

Twenty-first Annual Meeting Held at Bozeman, Mont., January 9, 10, 11, 1908.

Thursday. — The visiting members of the Society were met on the arrival of the afternoon trains by the entertainment committees, composed of the leading citizens of Bozeman, escorted to the Bozeman Hotel, where, after a brief rest, they were shown about town and afforded an opportunity to note the general prosperity manifestly evident on every hand. During the evening they were the guests of the Gallatin Valley Commercial Club and made to feel quite at ease through the generous hospitality of the numerous membership of that organization. Many old-time friendships were revived from acquaintances made, and too soon the hour for " dry " town folks was at hand.

Friday. — Promptly at the hour selected by the committee in charge of the day's program the members became the guests of the Bozeman Electric Railway Company, and were taken to the grounds of the Montana State College. A short time was devoted to the inspection of one of the college buildings and its magnificent equipment, whence, under the guidance of the resident members of the Society who are instructors in the college, the visitors were ushered into the presence of the students and faculty in the college auditorium assembled. A very cordial address of welcome by President Hamilton was followed by short talks on the part of prominent engineers. The college band delighted all listeners by their proficiency, and after a short time devoted to several class rooms and library, the real thing was placed before the visitors — something they wanted and could digest — in the shape of a superb luncheon prepared by the culinary artist students of the Domestic Science Department of the college. Here the Entertainment Committee struck a snag — the guests would not offer to proceed, and had they not exhausted the larder it is ikely that the engineers' meeting would have ended without another session. Appreciative words were said, gray-haired orphans called for " pie," and the swinging doors of the banquet hall creaked farewell. The remainder of the day was consumed in visiting the various departments of the college, furnishing advice to each other and the students, learning many new things not found in old books, and taking a special pride in this magnificent state school. Relays of instructors acted as guides, flocks and herds were at their best, and the balmy air brought comfort to every visitor. The evening entertainment was furnished by the Bouffon Club of the city and was of a social nature, made successful by the presence of Bozeman's fair dames and daughters.

Saturday. — The business session was called to order in the Agricultural Annex of the Gallatin Valley Commercial Club at 10 A.M., President E. C. Kinney presiding. Twenty-two members present. Minutes of last meeting read and approved. The Secretary read the applications for membership in the Society of Messrs. Tannatt, Dearborn, Locke, Kneale, Flaherty, Sacket and Davis, and after approval the necessary ballots were ordered. Edward Daniel Kinney, son of President Edward C. Kinney, was elected to membership by a unanimous vote. The Secretary presented the ballots of the officers elected; tellers counted the same and reported 43 ballots, all "yes." President Kinney declared the following officers elected for 1908: President, Archer E. Wheeler; First Vice-President, Charles H. Bowman; Second Vice-President, Frank M. Smith; Secretary and Librarian, Clinton H. Moore; Treasurer and Member of the Board of Managers of the Association of Engineering Societies, Samuel Barker, Jr.; Trustee for three years, John C. Adams. In the absence of President Wheeler, Vice-President Bowman acted in his stead. The annual reports of the Secretary and Treasurer were now read and referred to the Trustees. The Committee on Resolutions on the death of the late Charles A. Molson presented the following, which were read by the Secretary:

Whereas, God in his providence has removed from our midst Charles A. Molson, a member of this Society, now, therefore, be it

Resolved: That in the death of Charles A. Molson this Society has suffered an irreparable loss. His sterling qualities of head and heart were well known to his many friends, and his conscientious discharge of every duty intrusted to him is testified to by his employers as well as by those associated with him in the management and development of mines.

In 1888, and for many years following, he was actively engaged in the management of Montana mining properties. On leaving Montana he established his headquarters in Salt Lake City, and up to the time of his death he followed his chosen work of examining and reporting upon mining properties. He was known from Mexico to the British possessions as a thorough, honest and painstaking engineer.

Resolved: That this Society shall express, by these resolutions, its sincere sorrow on the death of Mr. Molson, and these resolutions shall be spread upon the minutes of the Society and a copy forwarded to his bereaved family.

B. S. DUNSHEE,
J. C. ADAMS,
C. H. MOORE,
Committee Montana Society of Engineers.

The amendment to the by-laws heretofore proposed was considered, and on motion rejected. The resignation of Howard D. McLeod and the request of Ambrose E. Ring for a transfer to the list of corresponding members received proper consideration. On motion, the Secretary was instructed to solicit the good offices of the Montana Congressional delegation in behalf of the bill granting aid to land grant colleges for engineering research, now pending in Congress. Several letters of regret from absent members were read, reminding many of early days. The Secretary then outlined the program for the afternoon and a recess was taken till 2 P.M. The afternoon session began at the hour named, Vice-President Bowman in the chair. A telegram from President Wheeler was read, regretting his unavoidable absence. The address of the retiring president, Edward C. Kinney, received the unstinted approval of a large and appre-

ciative audience. This address was followed by an account of the progress of the work of the Reclamation Service in Montana by H. N. Savage, engineer in charge. A paper by Mr. Joseph H. Harper on the subject "The San Francisco Earthquake," created much interest among its listeners, and another essay entitled "The Development of the West Coast of South America," by Mr. F. W. Blackford, received many favorable comments. A short talk on a "Placer Mining Fraud" in Wyoming, by Mr. E. W. King, completed the literary work of the day. The question of a midsummer meeting was next considered, and after considerable favorable discussion the trustees were instructed to try to hold a summer meeting during the current year. The usual banquet ended the actual work of the annual session.

Clinton H. Moore, *Secretary*.

Technical Society of the Pacific Coast.

San Francisco, February 15, 1908. — Annual meeting of the Technical Society of the Pacific Coast, held January 24, 1908. The following officers were duly elected to serve during the ensuing year:

President — George W. Dickie, Mechanical Engineer, San Mateo, Cal.

Vice-President — H. D. Connick, Assistant City Engineer, City Hall, San Francisco, Cal.

Secretary — Otto von Geldern, Consulting Civil Engineer, 1978 Broadway, San Francisco, Cal.

Treasurer — E. T. Schild, Manufacturer, 1908 Broadway, San Francisco, Cal.

Directors — Hermann Barth, Architect, 641 Mission St., San Francisco; Edw. F. Haas, Civil Engineer, 628 Montgomery St., San Francisco; L. A. Hicks, Civil Engineer, Humboldt Bank Building, San Francisco; Loren E. Hunt, Civil Engineer, University of California, Berkeley; C. B. Wing, Professor of Engineering, Leland Stanford, Jr., University, Palo Alto, Cal.

On the Board of Managers of the Association of Engineering Societies, the President, Mr. George W. Dickie, and the Secretary, Mr. Otto von Geldern, were chosen to act as heretofore customary.

A paper was read by Mr. George W. Dickie, the President of the Society, entitled "Mechanical Engineering as Practiced on the Atlantic and Pacific Coasts," which was ordered to be sent to the Journal for publication.

The meeting thereupon adjourned.

Otto von Geldern, *Secretary*.

Detroit Engineering Society.

Detroit, Mich., January 24, 1908. — Meeting called to order at 8.10 P.M., President E. S. Wheeler presiding.

Minutes of the regular meeting of December 20 read and approved.

The following candidates were elected to membership: Hugo Arnold,

Fred Lockwood, Sherman Moore, Thomas Russell, Melvin A. Gilbert, Otto S. Zelner.

The paper of the evening was presented by Francis C. Shenehon on "The Right of Way of the Great Lakes."

Discussion followed by the following: A. Geo. Mattsson, on "The Power of Boats on the Great Lakes"; C. Y. Dixon, on "The Detroit River"; Col. Chas. E. L. B. Davis, on "The Regulation of Navigation in the Various Channels"; Edward Molitor, on "Cost and Preparing Lake Charts"; Geo. H. Fenkell, on "Distribution of Water for Drinking Purposes"; F. G. Ray, on "Unknown Shoals and Hidden Obstructions."

Moved by B. E. Parks, seconded by A. Geo. Mattsson, that the Society tender Col. Chas. E. L. B. Davis a vote of thanks for the valuable collection of books presented to the Society. Carried.

Members present, fifty-one.

Moved that we adjourn. Carried.

BAMLET KENT, *Secretary.*

Louisiana Engineering Society.

Synopsis of Proceedings of the Last Six Months.

DURING the months of July and August no meetings were held, the Society following the usual custom of adjourning for these two months.

The first regular meeting after this summer adjournment was held on September 9, 1907, which proved to be the last one held in the old quarters of the Society in the Tulane-Newcomb Building. Mr. G. W. Lawes read an interesting paper entitled, "Subaqueous Phenomena at the Mouth of the Mississippi." An informal discussion followed, which brought out very interesting facts.

The meeting of October 14 was held at the new headquarters of the Society in Gibson Hall, Tulane University. The Society was welcomed to its new home by Prof. W. H. P. Creighton, who spoke of the advantages resulting from the union of the two forces and from the merging of the two libraries of Tulane University and the Louisiana Engineering Society, and expressed the hope that both would see lots of good resulting from the closer union. Mr. G. W. Lawes replied with a word of appreciation, a bit of history, a bright outlook for the future and a prediction of the good results in store for the Society and for Tulane University. Major B. M. Harrod, by request, spoke upon the recent change, outlined the growth of the idea and expressed his entire satisfaction with the work accomplished. The meeting then adjourned to visit the Tilton Memorial Library of the University, in which the library of the Society has been placed.

At the meeting of November 11, Mr. G. W. Lawes read a short paper on "High Buildings in New Orleans," which paper he said was written to invite discussion on so important a subject. A discussion fully entered into by all the members followed.

The meeting of December 12 was well attended. Mr. M. P. Robertson read a most interesting and entertaining paper entitled "Some His-

torical Facts as to the Discovery and Use of the Magnetic Needle and Some Facts from the Author's Experience with the Compass and Jacob's Staff in Land Surveying in Louisiana." Nominations of officers to serve for 1908 were had as follows: For President, C. W. Wood and M. P. Robertson; for Vice-President, J. T. Eastwood and John Riess; for Secretary, A. C. Duval and L. C. Datz; for Treasurer, J. C. Haugh and A. L. Black; for Director, J. W. Armstrong and Marcel Garsaud; for Member of Board of Managers of the Association of Engineering Societies, G. W. Lawes. It was then decided to have the annual meeting followed by the annual banquet.

On January 11, 1908, this meeting was held at the New Denechaud Hotel. The annual reports of the Board of Direction, Secretary, Treasurer and Library Committee were read. A membership of 107 and a balance cash on hand of $370.52 were shown. The ballots for the election of officers were counted and the following were declared elected: C. W. Wood, President; J. T. Eastwood, Vice-President; L. C. Datz, Secretary; J. C. Haugh, Treasurer; Marcel Garsaud, Director; G. W. Lawes, Member Board of Managers of the Association of Engineering Societies.

Mr. Wood, in a few well-chosen words, thanked the Society for the honor. The newly elected officers were then installed.

Mr. Lawes, the retiring President, read his annual address, after which the meeting adjourned to the banquet hall, Mr. H. J. Malochee acted as toastmaster, and an evening of good fellowship and interesting talks prevailed.

Association of Engineering Societies.

Vol. XL. MARCH, 1908. No. 3.

PROCEEDINGS.

Engineers' Club of St. Louis.

St. Louis, February 5, 1908. — The 645th meeting of the Engineers' Club of St. Louis was held at the Club rooms, 3817 Olive Street, Wednesday evening, February 5, 1908, at 8.30 o'clock. President Brenneke presided. Forty-nine members and thirteen visitors were present.

The minutes of the 644th meeting were read and approved, and the minutes of the 437th meeting of the Executive Committee were read.

Applications were presented from the following: Albert Belding Gaines, Jr. (member), Walter Leo Hempelmann (member), Frank E. Washburn (member), William J. McCully (associate member).

The following were elected: Benjamin McKeen (member), Donald G. Scott (member), Walter E. Bryan (junior).

The Secretary read an invitation received from the University of Illinois to send a representative to the installation of Prof. W. F. M. Goss as Dean of the College of Engineering on Wednesday, February 5. It was announced that Mr. O. Stephensen, a member of the Club now resident in Urbana, Ill., had been asked to represent the Club at this function.

The paper of the evening, on "Some of the Problems Involved in the Construction of a Deep Waterway from the Lakes to the Gulf," was then read by Col. J. A. Ockerson. The paper discussed the problems to be solved in constructing the waterway in the several reaches of the river, namely, from Chicago through the Illinois River to Grafton; from Grafton to St. Louis; from St. Louis to Cairo; and from Cairo to the Gulf. Lantern slides were freely used to illustrate the different points presented.

An interesting discussion at the close of the reading of the paper was participated in by Mr. W. K. Kavanaugh, of the Inland Waterways Commission; Mr. James E. Smith, President of the Business Men's League; Mr. Edward Devoy, President of the Merchants' Exchange; Mr. W. F. Saunders, Secretary of the Business Men's League; and by Colonel Ockerson, Mr. Robert Moore and Mr. Julius Pitzman.

Adjournment.

A. S. Langsdorf, *Secretary.*

St. Louis, February 19, 1908. — The 646th meeting of the Engineers' Club of St. Louis was held at the Club rooms, 3817 Olive Street, on Wednesday evening, February 19, at 8.30 o'clock. President Brenneke presided. There were present twelve members and seven visitors.

The minutes of the 645th meeting were read and approved.

The Secretary read a letter from Miss Mary J. Klem, Librarian of the Academy of Science, requesting that a representative of the Engineers' Club be appointed to attend a conference to discuss ways and means for increasing the efficiency and usefulness of the various technical libraries of the city. It was announced that the Librarian of the Club had been appointed by the chairman as a representative at this conference.

The following applications were presented: Rolla Copley Bulkeley (member), Fred Lyle Bunton (member), Robert Hasbrouch Wyld (member), Harold Cantwell Burgess (junior).

The following were elected: Albert Belding Gaines, Jr. (member), Walter Leo Hempelmann (member), Frank E. Washburn (member).

There being no further business, the paper of the evening on the Photometry of Electric Lamps was presented by Mr. George W. Lamke. There were described in detail the various methods used for the determination of horizontal candle-power, mean horizontal candle-power, mean spherical candle-power and mean hemispherical candle-power; also descriptions of the apparatus used in these determinations, illustrated by lantern slides, as well as of the various standards of light adopted as to basis of comparison.

At the conclusion of the reading of the paper an interesting discussion was participated in by Dr. Hyde, of the United States Bureau of Standards, and by Mr. Rollins, of the Electrical Testing Laboratory of New York City, both of whom are specialists in electric lamp photometry. Mr. A. S. Langsdorf also participated in the discussion.

Adjourned.

A. S. Langsdorf, *Secretary.*

The Civil Engineers' Club of Cleveland.

Regular Meeting, February 11, 1908, at the Club Rooms, called to order by President Wright at 8 p.m. Present, 60 members and visitors.

Minutes of preceding meeting read and approved.

The tellers, Messrs. Horner and E. B. Thomas, reported the election to Active Membership of Frank Van McMullin.

The application of William Edmund Simpson, approved by the Executive Board, was read.

The Nominating Committee presented the following nominations for officers for the ensuing year:

President — Willard Beahan.
Vice-President — Robert Hoffmann.
Secretary — J. C. Beardsley.
Treasurer — J. H. Fox.
Librarian — George H. Tinker.
Directors — H. E. Baldwin, W. O. Henderer.

On motion of Mr. Lane, the report of the committee was accepted.

Amendments to the constitution, submitted by the Executive Board, were read by the Secretary. After some discussion by Messrs. Ritchie, Palmer and Green, on motion of Mr. B. L. Green, the Secretary

was directed to have the proposed amendments printed and mailed to the members for discussion at the April meeting of the Club.

Mr. W. J. Springborn, President Board of Public Service, gave a "Description of the Cleveland Garbage Disposal Plant and Methods in Use in Operation," illustrated by many lantern slides. Discussion was taken part in by Messrs. Lane, Rowe, Prentiss, Wenzell and others.

On motion of Mr. Osborn, a vote of thanks was tendered Mr. Springborn.

Adjourned.

J. C. Beardsley, *Secretary*.

Annual Meeting, March 10, 1908, at the Cleveland Athletic Club, called to order by President Wright at about 9.30 P.M. Present, 76 members and 32 guests.

Reading of minutes dispensed with.

Applications for Active Membership of the following, approved by the Executive Board, were read by name only: Clinton L. Denison, John H. Lesh, David W. Morrow and Albert H. Tait.

The tellers, Messrs. C. W. Brown, Lane and Westcott, reported the election to Active Membership of Mr. William E. Simpson and of the following officers for the ensuing year:

President — Willard Beahan.
Vice-President — Robert Hoffmann.
Secretary — Joseph C. Beardsley.
Treasurer — John H. Fox.
Librarian — Geo. H. Tinker.
Directors (term expires 1910) — Hiram E. Baldwin, William O. Henderer.

Letters from Messrs. Jos. Leon Gobeille, C. H. Benjamin and N. P. Bowler were read by the Secretary.

Printed reports of the Secretary and Treasurer, hereto appended, were submitted and accepted.

The program, hereto appended, shows the manner in which the body was refreshed and the soul uplifted.

Adjourned.

J. S. Beardsley, *Secretary*.

Twenty-eighth Annual Meeting and Banquet of the Civil Engineers' Club of Cleveland at the Cleveland Athletic Club.

Toasts:

Charles H. Wright, presiding.

"I was thinking to-night, as I sat in the cars,
With charmingest prospect of fragrant cigars,
With a sip of good coffee, how mean it would be,
If that cannibal president calls upon me."

Our New President.

Willard Beahan.

"I thank you, Mr. President, you've kindly broke the ice;
Virtue should always be the first, 'till now I've been the vice —
(A *vice* is something with a screw that's made to hold its jaw
'Till some one twists the handle and opens up its maw)."

THE ENGINEER'S RELATION TO INDUSTRIAL EDUCATION.

Dr. Charles S. Howe.

" With a stuffing of praise, and a basting of wit,
You may twitch at your collar, and wrinkle your brow,
But you're up on your legs, and you're in for it now."

CIVIC ART.

Wm. H. Hunt.

" Little beds of flowers, little pots of paint,
Make a handsome cottage out of one that ain't."

ENGINEERING AND THE LAW.

Newton D. Baker.

" Come you of the law, who can talk, if you please,
Till the man in the moon will allow it's a cheese,
And tell of the lady, ' that never tells lies,
And stands with a kerchief tied over her eyes.' "

MUSIC.

ENGINEERING ACCOMPLISHMENTS OF THE YEAR.

President's Address.

" Close the door and dim the light,
I shall not read to you to-night.
No, I am not sleepy, near —
Do not go, stay with me here.
In the darkness of the place
I'll a season's progress trace."

FINANCIAL REPORTS OF SECRETARY AND TREASURER FOR YEAR ENDING FEBRUARY 29, 1908.

SECRETARY'S REPORT.

Permanent Fund.

Balance, March 1, 1907		$1 132.52	
Fees	$140.00		
Interest	42.36	182.36	
Transferred to General Fund			$150.00
Balance, February 29, 1908			1 164.88
Total		$1 314.88	$1 314.88

General Fund.

Balance, March 1, 1907		$202.23	
Dues, Active	$1 862.50		
Associate	112.00		
Corresponding	125.00		
Delinquent	201.50	2 301.00	
1906 bills			$327.15
Rentals		486.00	1 000.00
Billiards		66.95	59.00
Keys		.50	
Advertising		97.00	4.00
Books and periodicals			121.10
Program			122.20
Running expenses			51.20
JOURNAL		25.50	139.74
Furniture and fixtures		315.75	677.86
Printing		12.00	298.70
Postage			96.35
Stationery			25.92
Carried forward		$3 506.93	$2 923.22

Brought forward		$3 506.93	$2 923.22
Secretary			200.00
Telephone (extra name)			9.00
Taxes			12.88
Commissions			9.20
Repairs			14.50
Custodian			337.00
Transferred from Permanent Fund		150.00	
Balance, February 29, 1908			151.13
		$3 656.93	$3 656.93

Summary.

March 1, 1907, balance, Permanent Fund	$1 132.52	
March 1, 1907, balance, General Fund	202.23	
Receipts, Permanent Fund	182.36	
Receipts, General Fund	3 454.70	
Andrew Carnegie	1 000.00	
Disbursements, Permanent Fund		$150.00
Disbursements, General Fund		3 505.80
February 29, 1908, balance, Permanent Fund		1 164.88
February 29, 1908, balance, General Fund		151.13
February 29, 1908, Library (Proposed Fund)		1 000.00
	$5 971.81	$5 971.81

Bills Receivable.

From members (dues)	$356.50
Other clubs	169.00
Billiards	7.65
Miscellaneous	.80
	$533.95

Bills Payable.

Association of Engineering Societies	$131.00
Caxton Building Company	201.32
	$332.32

Respectfully submitted,

Joe. C. Beardsley, *Secretary.*

TREASURER'S REPORT.

Permanent Fund.

Receipts:			
Balance on hand March 1, 1907	$1 132.52		
Entrance fees	140.00		
Interest	42.36		
		$1 314.88	
Expenditures:			
Transferred to General Fund		150.00	
Balance on hand February 29, 1908		$1 164.88	$1 164.88

General Fund.

Receipts:			
Balance on hand March 1, 1907	$202.23		
From Secretary to February 29, 1908	3 304.70		
From Permanent Fund	150.00		
From Andrew Carnegie	1 000.00	$4 656.93	
Expenditures		3,505.80	
Balance on hand February 29, 1908		$1 151.13	$1 151.13
Grand total on hand February 29, 1908			$2 316.01

Respectfully submitted,

R. O. Rote, *Treasurer.*

Boston Society of Civil Engineers.

Boston, Mass., February 19, 1908. — A regular meeting of the Boston Society of Civil Engineers was held at Lorimer Hall, Tremont Temple, at 7.45 o'clock P.M., President F. W. Howe in the chair. One hundred and twenty members and visitors present, including ladies.

On motion of Mr. J. C. Chase the reading of the records of the last meeting was dispensed with.

Messrs. Thomas G. Hazard, Jr., Walter T. Wiley and Dana M. Wood were elected members of the Society.

At 8 o'clock a joint meeting with the Appalachian Mountain Club was held and the President invited Mr. Gardner M. Jones, President of the Appalachian Mountain Club, to assume the chair.

Mr. Jones then presented the speaker of the evening, Mr. Allen Hazen, a member of both societies, who gave a very interesting description of " A Short Trip in Australia," which was illustrated by a large number of lantern slides.

Adjourned.

S. E. Tinkham, *Secretary.*

Sanitary Section.

The annual meeting of the Sanitary Section of the Boston Society of Civil Engineers was held at the Society rooms Wednesday evening, March 4, 1908, with thirty-five members present.

The report of the Executive Committee was read by the chairman and was accepted and placed on file.

The report of the Run-off Committee was read by the chairman of the committee and was accepted and placed on file.

Upon motion of Mr. H. K. Barrows it was voted that the Run-off Committee be continued and that Messrs. Arthur T. Safford and William S. Johnson be added to the committee.

Upon motion of Mr. H. P. Eddy, it was voted that a committee of three be appointed by the chair to collect sewerage statistics and prepare them for publication. The chair appointed Messrs. H. P. Eddy, Bertram Brewer and Charles Saville as members of this committee.

The following officers were elected for the ensuing year:

Chairman — William S. Johnson.
Vice-Chairman — George A. Carpenter.
Clerk — Irving T. Farnham.
Members of the Executive Committee — Hector J. Hughes, Edgar S. Dorr, Charles R. Felton.

An illustrated talk upon the subject of water power was given by Mr. Arthur T. Safford.

William S. Johnson, *Clerk.*

Annual Report of the Executive Committee of the Sanitary Section.

The Executive Committee of the Sanitary Section makes the following report of the meetings held and attendance during the year 1907–8:

March 6, 1907. Subject: "Wastes from Lowell Gas Light Company's Yard," by Arthur T. Safford. Attendance, 31.

May 1, 1907. Subject: "Run-off from Sewered Areas; Methods Adopted for Securing Data and Results Accomplished." General discussion. Attendance, 38.

June 5, 1907. "Excursion to Sewage Disposal Works and Water Purification Plant at Providence, R. I." Attendance, 38.

November 15, 1907. Subject: "Purification of Boston Sewage; Experimental Results and Practical Possibilities." By Professors C.-E. A. Winslow and E. B. Phelps. Attendance, 61.

December 4, 1907. Subject: "Pollution of Waters at Common Law and Under Statutes." By Charles F. Choate, Jr., Esq. Attendance, 45.

The present number of members of the Section who are also members of the Society is 156; there are 3 associates who are also associates of the main society and 20 who are members of the Sanitary Section only, a total of 179.

The Section through a special committee has already collected sewerage statistics from cities and towns under a uniform method of reporting formulated by the committee, and this work is being continued by the Clerk. The results will be ready for publication within a short time.

The Section through another committee appointed for the purpose is now at work upon the run-off from sewered areas and this committee has already made and published a preliminary report. The Section is very fortunate in having members with enthusiasm enough to devote their time to this work and they should not be allowed to do all the work themselves. All members of the Section to whom a personal appeal for assistance in this work has been made should respond, not only on account of its value to the engineering world at large, but because of the personal interest aroused in experimental work of a very high character.

There are a number of other lines of work, such as "uniform specifications for sewer pipe," which should be given to committees. In order to make the work of this Section valuable and keep up the interest, something should be done each year in the way of original research, for which the time and money should be provided. The committee hopes to see a fund made available for such work, by which these matters can be given the personal attention of some one, a member of the Section, who can be paid for his services.

The committee desires again to call to the attention of the Section the fact that there are not many members of the Section outside of those who are also members of the Boston Society. The Section was organized principally to bring together the engineers and the men who are connected officially with the care and management of sewerage works. It is, therefore, the duty of every one to bring to the attention of such officials, and others interested, the work of the Section and the possibilities of greater activity through an increase in the membership. We must make this a personal duty and increase the number of Section members just as far as possible.

In this connection the Section finds it difficult to get papers from men in actual charge of sanitary work and maintenance, and it is a matter of regret that this should be so. We would urge upon the members the fact that in order to make the work of the Section well balanced, we should be

able to obtain papers and discussions from those members who are fortunate enough to know the practical difficulties in the way of getting good results.

Respectfully submitted,

ARTHUR T. SAFFORD, *Chairman.*

REPORT OF COMMITTEE ON RUN-OFF.

BOSTON, MASS., MARCH 4, 1908. — The Committee on Run-off from Sewered Areas submits the following report of its work during the year 1907:

The work of your committee has been confined almost entirely to investigations, plans and correspondence looking to the establishment of stations for making observations. There have been held five meetings of the committee, which were well attended, and numerous meetings of subcommittees. The committee now has nine stations assured from which observations will be made during 1908, and expects to largely increase this number in the near future.

Early in the year the committee found that it must be prepared to recommend apparatus, give an estimate of the cost and advise as to the installation as well as to the method of collecting and recording the data; and for the purpose of presenting the conclusions of the committee and the information which had been collected to members of the profession who would help in the work by establishing observation stations, submitted a preliminary report on these matters, an important feature of which was the collecting and listing of such papers covering the subject as had already been printed. Printed copies of this report have been widely distributed, and other copies will be furnished upon application.

The committee has received many favorable commendations as to the desirability and value of this work, but has found that many whose cooperation is needed hesitate to install and operate the needed apparatus. This is partly on account of the expense, but probably largely due to the fact that the necessity of collecting this information is not generally understood among members of city governments, and the engineer hesitates to introduce a proposition which will not be appreciated and which may cause criticisms. The committee believes that, in presenting the proposition, it should be represented that the information to be obtained will be of service in answering claims which may be brought against the municipality on account of insufficient drainage or because of overflow from drains already built; that the observations and collated results will be of great value in determining the sizes of storm water drains with more exactness than is now possible and should result in increased ultimate economy in the construction of drainage systems.

This is a work which must necessarily extend over a long period of time, for after a sufficient number of stations have been established, the period of observations must cover at least two years in order to study the results of varying intensities of rainfall. Your committee expects to furnish to each observer compilations of the data as it is collected, together with the conclusions derived from the same. The committee reiterates the statement made in the preliminary report that "while the Sanitary Section, through its committee, has taken the initiative in starting this investigation, the function of the committee will be merely that of a clearing house.

The value of the results must depend upon the number and interest of those who coöperate." Such coöperation by every member of the Section is earnestly solicited.

Respectfully submitted,

Lewis M. Hastings,
Irving T. Farnham,
Geo. A. Carpenter,
Hector J. Hughes,
Harrison P. Eddy, *Committee.*

Boston, March 18, 1908. — The annual meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.30 o'clock P.M., President Edward W. Howe in the chair, 81 members and visitors present.

The record of the last meeting was read and approved.

Mr. Joseph P. Davis, a past President of the Society, was elected an honorary member, and Messrs. William W. Churchill, Harold P. Farrington, Howard G. Harrison, John F. Peterson and Charles S. Tinkham were elected members of the Society.

The Secretary read the annual report of the Board of Government and, on motion, it was accepted and placed on file.

The Secretary then read his annual report and, on motion, it was also accepted and placed on file.

The Treasurer read his annual report and, on motion, it was accepted and placed on file.

Mr. Street presented and read the annual report of the Committee on Excursions. On motion, the report was accepted and placed on file.

The Librarian read the annual report of the Committee on the Library and, on motion, it was accepted and placed on file.

Mr. Johnson presented and read the annual report of the Committee on Advertisements. On motion, it was accepted and placed on file.

The Secretary read a short note from Mr. FitzGerald, Chairman of the Committee on Quarters, stating that the committee had held no meetings during the year, and that "the quarters now at Tremont Temple, while, perhaps, hardly as satisfactory as we might wish, do not seem to call for an immediate change." On motion, the report was accepted.

The Secretary read the following communication, entitled "A plea for a larger membership and a club house":

To the Members of the Boston Society of Civil Engineers:

The writer wishes to bring a matter before the Society that has long been uppermost in his mind. It concerns making the Society more of a social body than he feels that it now is. To make even a suggestion as to any improvement in the running of such an old and well-organized body as the Boston Society of Civil Engineers may seem presumptuous, but the writer hopes that any suggestions or criticisms that follow will be received in the spirit that they are offered.

To begin with, we do not seem to attract a sufficiently large number of engineers to our membership. During the past twelve months we have had only 46 applications for membership, of which number the writer secured 5, and it was only by strenuous recruiting that he induced these 5 to join our ranks. From 1904 to 1907 the Boston Society gained in membership only $7\frac{1}{2}$ per cent., whereas the American Society of Civil Engineers, for example, showed a gain of about 34 per cent. in the same period.

In May, 1907, our Society had 628 members, of whom about 280 were

registered from Boston proper, about 450 from Massachusetts and the rest, about 180, from points outside the state. Our membership in Boston proper, not to mention "Geater Boston," seems to the writer to be too small. Statistics show that there were, in 1907, 125 civil engineering graduates from the Massachusetts Institute of Technology registered from Boston. There are no doubt three times that number here who have spent some time at the Institute. Add to this legion the numerous engineers who followed other branches of the engineering profession at the Institute, the large number of alumni of other technical schools and the great body of able engineers who received no collegiate technical training, and a casual glance, with most modest methods of estimating, will clearly show that we have not one half the resident membership that we ought to have, not only for our own sakes, but for the good of those who have neglected to affiliate with us up to the present time. The same condition of affairs obtains to a greater or less degree throughout the state.

As regards members from outside of Massachusetts, and particularly outside of New England, we can hardly expect to attract many new ones, but we certainly do want to retain the old ones and any present resident members who may move away.

A great many young engineers to whom the writer has suggested membership have declined on the ground that they preferred to join the American Society of Civil Engineers. The main attractions that the American Society possesses for a non-resident member are a supposed prestige and the excellent literature furnished. The effect of these attractions on some of the younger engineers is best shown by the Junior members of the American Society of Civil Engineers registered from Boston in 1907. Of nine such members only one belongs to both societies, whereas of the 100 corporate members of the American Society, 72 are also members of the Boston Society. Can we not attract the younger engineers to our Society before they seek membership in the great national society?

The question naturally arises as to how to increase our membership. At present this depends almost entirely on the individual efforts of the members of the Society, and there is not the slightest doubt that with each resident member acting as a committee of one, at least two hundred desirable new members might be readily obtained during the coming twelve months. This would mean an average of less than one for each member.

The greatest handicap to the social side of our Society seems, to the writer, to be the unsuitable place that we now have for our headquarters and for holding our meetings. To have our meeting place in a temple of Worship, where a certain feeling of restraint antagonistic to good-fellowship is ever present, seems decidedly incongruous. A new and suitable home seems to be the only true solution, and that at an early date.

That the rank and file of our Society are social beings, seeking recreation and good-fellowship as well as technical instruction and entertainment, is clearly evinced by the attendance both at meetings and on excursions where the purely technical part is judiciously tempered with sociability. We have only to refer to the large attendance at such functions to conclusively prove this statement.

The writer has no particular suggestions to make as to the exact method to pursue in arranging for the acquisition of a suitable club house. He hopes, however, that the Society will give the matter even more earnest consideration than heretofore and that the score or more gentlemen, already members for more than a third of a century, whom we are fortunate in now honoring as so-called "original" members, may all be with us when we dedicate the building to be used as a permanent home for the Boston Society of Civil Engineers.

LUZERNE S. COWLES,
Member Boston Society of Civil Engineers.

BOSTON, March 18, 1908.

After a discussion of the subject-matter of the communication, on motion of Mr. Fernald, it was voted: "That a special committee of five

be appointed to investigate and report upon the question of securing new quarters along the lines outlined in the communication of Mr. L. S. Cowles, of March 18, 1908." It was also voted that the incoming President be requested to appoint this committee.

On motion of Mr. Adams, the recommendation of the Board of Government appropriating the sum of $50 for standard engineering books was adopted.

On motion, duly seconded, it was voted to refer to the Board of Government, with full powers, the continuation and appointment of the several special committees of the Society.

Messrs. Mayo T. Cook and John N. Ferguson, the tellers of election, reported the results of the letter ballot and in accordance with their report the following officers were declared elected:

President — Joseph R. Worcester.
Vice-President (for two years) — Henry F. Bryant.
Secretary — S. Everett Tinkham.
Treasurer — William S. Johnson.
Librarian — Frederic I. Winslow.
Director (for two years) — George Bowers.

Mr. William F. Williams then read the paper of the evening entitled, "The Abolition of Grade Crossings in New Bedford." The paper was illustrated by lantern slides.

Adjourned. S. E. Tinkham, *Secretary.*

Twenty-sixth Annual Dinner.

The twenty-sixth annual dinner of the Boston Society of Civil Engineers was served at the Hotel Vendome, Boston, Tuesday evening, March 10, 1908, and was attended by 161 members and guests. The usual informal reception was held at six o'clock and the dinner was served at seven o'clock.

The special guests of the Society were Mr. Charles Macdonald, President American Society of Civil Engineers; Mr. Fred. J. Miller, Vice-President American Society of Mechanical Engineers; Hon. Walter C. Wardwell, Mayor of Cambridge; President Arthur A. Noyes of the Massachusetts Institute of Technology; Hon. Charles F. Choate, Jr., of Boston; Mr. Frank B. Gilbreth, of New York, and Mr. Sylvester Baxter, Secretary of the Metropolitan District Improvement Commission.

A pleasing innovation at this year's dinner took the form of some original verses contributed by members of the Society and fitted to popular tunes, which were sung, between the courses, by those present, led by a quartet of members.

At the conclusion of the dinner the President of the Society, Mr. Edward W. Howe, introduced successively the several speakers: Mr. Macdonald, who brought the fraternal greetings of the American Society of Civil Engineers; Mr. Miller, who spoke for the Mechanical Engineers and urged the formation of a mechanical section of the Society; Mayor Wardwell, who alluded to the days when he was associated in civil engineering work with some of the members whom he saw present; and Mr. Choate, who spoke for the legal profession.

Mr. Wm. E. McClintock, a past president of the Society, reminded members that at the dinner a year ago the full program could not be carried out owing to the sickness of the perennial committee on dinner,

Mr. Manley, and the gift which had been prepared to present him at th dinner was sent to his house. He felt that the members would be glad to hear now the word from Mr. Manley which was missed last year. Mr. Manley on rising was received by hearty applause and another musical effusion from those present. Mr. Manley expressed his appreciation of the many honors which the Society has conferred upon him, of the confidence which had been placed in him by the call to arrange the annual dinner for these twenty-six years and above all for the beautiful gift which had been sent him a year ago, coming at the time when such a remembrance struck a more responsive chord, if possible, than at any other time. Music was furnished by the Albion Quartet.

ANNUAL REPORT OF THE BOARD OF GOVERNMENT FOR THE YEAR 1907–1908.

BOSTON, MASS., March 18, 1908.

To the Members of the Boston Society of Civil Engineers:

In compliance with the requirements of the constitution, the Board of Government submits its report for the year ending March 18, 1908.

At the last annual meeting the total membership of the Society was 635, of whom 600 were members of the Society, 2 honorary members, 13 associates and 20 were members of the Sanitary Section only.

During the year the Society has lost a total of 21 members: 12 by resignation, 6 by forfeiture for non-payment of dues and 3 have died.

There have been added to the Society during the year a total of 36 members in all grades; 33 by election and 3 by reinstatement.

The present membership of the Society consists of 1 honorary member, 13 associates and 636 members, of whom 18 are members of the Sanitary Section only; making the total membership 650.

Record of deaths during the year is:

Charles H. Haswell, honorary member, died May 12, 1907.

Frank W. Upham, died May 3, 1907.

Alfred E. Nichols, died July 31, 1907.

In the death of Mr. Haswell the Society lost its oldest member, one whose membership dates from June 3, 1850, a record of nearly fifty-seven years.

Ten regular meetings of the Society have been held during the year, and the twenty-sixth annual dinner was given at the Hotel Vendome on March 10, 1908. The average attendance at the regular meetings was 76, the largest being 120 and the smallest 35. The attendance at the annual dinner was 161.

At the regular meetings the following papers have been read:

March 20, 1907. — President Frank W. Hodgdon, "Difficulties Encountered in Early Surveys of the State of Massachusetts; How They were Overcome and the Results Obtained."

April 17, 1907. — Memoir of Nelson Spofford, by committee of the Society. Mr. George B. Francis, "Pennsylvania Terminal Station in New York City and the Engineering Problems Connected Therewith." (Illustrated.)

May 15, 1907. — Memoir of John E. Cheney, by committee of the Society. Mr. Thomas MacKellar, "The Simplex System of Concrete Piling" (Illustrated); Mr. Charles R. Gow, "Concrete Piles" (Illustrated).

June 19, 1907. — An illustrated talk by Mr. Desmond FitzGerald.

September 18, 1907. — Memoirs of Charles H. Haswell and Frank W. Upham, by committees of the Society. Mr. Herman K. Higgins, "Panama from the Human Side." (Illustrated.)

October 16, 1907. — Mr. Edward W. DeKnight, of New York, "Waterproof Engineering." (Illustrated.)

November 20, 1907. — Mr. Stephen Child, "Civic Centers and the Grouping of Public Buildings, with Suggestions for Boston." (Illustrated.)

December 18, 1907. — Mr. W. M. Davis, of Boston, "Economical Lubrication in Large Plants"; Mr. E. G. Bailey, of Boston, "Furnace Design in Relation to Fuel Economy."

January 20, 1908. — Mr. H. A. Carson and Mr. Wm. J. Wilgus, of New York, "Double Track Railroad Tunnel under the Detroit River at Detroit." (Illustrated.)

February 19, 1908. — Mr. Allen Hazen, "A Short Trip in Australia." (Illustrated.)

Four informal meetings have been held in the Society's library during the year.

December 11, 1907. — Discussion "on Methods of Finishing Concrete Surfaces," opened by Prof. L. J. Johnson.

January 8, 1908. — "Difficulties Encountered in the Town Boundary Survey and the Application of Plane Table Work to Portions of the Survey," by Mr. Henry B. Wood.

January 29, 1908. — "Description of a Concrete Steel Parkway Bridge in Cambridge," by Mr. Lewis M. Hastings.

February 12, 1908. — Discussion of papers read at the December meeting on "Lubrication of Large Plants," and on "Furnace Design in Relation to Fuel Economy."

From the Treasurer's report it will be learned that the finances of the Society are in good condition and that there has been a substantial gain in the Permanent Fund and in the unexpended balance of the Current Fund. A change has been made in the investment of about ten thousand dollars of our Permanent Fund. This was made necessary by the maturing of shares in coöperative banks and the near approach to the legal limit of our accounts in some of the savings banks. The reinvestments were made by the Treasurer by direction of the Board and with the advice of a special committee appointed for the purpose.

The lease of our quarters will expire on June 1, next. As the changes made at the time of the last renewal of our lease have afforded sufficient space for the probable growth of the library during the next three years, the Board recommends a renewal of the lease for that time.

The report of the Executive Committee of the Sanitary Section shows that the Section has had a successful year, with the usual number of meetings, which have been well attended and been of considerable interest and profit. Experience thus far shows the wisdom of the establishment of this Section, and it is the opinion of the Board that it would be of great benefit to the Society if sections interested in other special branches could be organized.

The Board endorses the recommendation of the Library Committee that the practice of buying standard engineering books be continued, and that the sum of $50 be appropriated for that purpose for the coming year.

For the Board of Government,

Edward W. Howe, *President.*

Abstract of the Treasurer's and the Secretary's Reports for the Year 1907–1908.

CURRENT FUND.

Receipts:		
Dues for 1905–1906	$13.00	
Dues for 1906–1907	8.00	
Dues for 1907–1908	3 992.00	
Dues for 1908–1909	101.00	
Rent of rooms	1 000.00	
Advertisements	595.00	
Library fines	3.25	
Permanent Fund, payment of loan	63.95	
Balance on hand, March 20, 1907	385.69	
		$6 161.89
Expenditures:		
Rent	$1 995.00	
Lighting	31.03	
Association of Engineering Societies	1 272.00	
Printing, postage and stationery	986.62	
Salaries of Secretary, Librarian and Custodian	550.00	
Reporting meetings	128.38	
Stereopticon	90.00	
Annual dinner	80.60	
Books	41.75	
Binding	97.25	
Periodicals	26.50	
Furniture and repairs	28.00	
Advertisements in JOURNAL	15.00	
Incidentals	229.73	
		5 571.86
Balance on hand, March 18, 1908		$590.03
Amount to the credit of Current Fund, March 20, 1907		449.64
Excess of receipts over expenditures		$140.39

PERMANENT FUND.

Receipts:		
Thirty-three entrance fees	$330.00	
Interest on deposits in savings banks	270.08	
Interest on bonds	126.00	
Interest on deposits in trust company	19.26	
Subscription to Building Fund	100.00	
Workingmen's Co-operative Bank, 21 matured shares	4 228.35	
Volunteer Co-operative Bank, 25 matured shares	5 033.75	
Withdrawn from savings banks	4 500.00	
		$14 607.44

Expenditures:

Merchants' Co-operative Bank, dues on 25 shares,	$300.00	
Volunteer Co-operative Bank, dues on 25 shares .	275.00	
Workingmen's Co-operative Bank, dues on 25 shares....................................	321.00	
Franklin Savings Bank, deposit...............	34.58	
Warren Institution for Savings, deposit.........	51.72	
Boston Five Cents Savings Bank, deposit.......	51.18	
Provident Institution for Savings, deposit.......	38.87	
Eliot Five Cents Savings Bank, deposit.........	49.08	
Institution for Savings in Roxbury, deposit......	44.65	
$4 000 Boston Elevated Railway Bonds..........	4 038.00	
$3 000 American Tel. & Tel. Co. Bonds.........	2 371.08	
$3 000 C. B. & Q. Joint Bonds.................	2 553.75	
Twenty-one shares Volunteer Co-operative Bank,	2 895.00	
Current Fund, repayment of loan...............	63.95	
		13 087.86
Balance on hand, March 18, 1908.....................		$1 519.58

PROPERTY BELONGING TO THE PERMANENT FUND, MARCH 18, 1908.

Twenty-five shares Merchants' Co-operative Bank...........	$3 051.16
Twenty-five shares Volunteer Co-operative Bank...........	3 099.40
Twenty-five shares Workingmen's Co-operative Bank.......	516.44
Deposit in Franklin Savings Bank........................	487.46
Deposit in Warren Institution for Savings.................	732.21
Deposit in Boston Five Cents Savings Bank...............	703.65
Deposit in Provident Institution for Savings...............	688.99
Deposit in Eliot Five Cents Savings Bank.................	546.18
Deposit in Institution for Savings in Roxbury...............	509.95
Republican Valley Railroad Bond, 6% par value...........	600.00
Boston Elevated Railway Bonds, 4½% par value...........	4 000.00
C. B. & Q. Railroad Joint Bonds, 4% par value............	3 000.00
American Tel. & Tel. Co. Bonds, 4% par value............	3 000.00
Cash on deposit....................................	1 519.58
Total Permanent Fund............................	$22 455.02
Amount of fund as per last annual report..............	20 058.27
* Gain during the year	$2 396.75

TOTAL PROPERTY OF THE SOCIETY IN THE POSSESSION OF THE TREASURER.

Permanent Fund.....................................	$22 455.02
Current Fund.......................................	590.03
Total..	$23 045.05
Amount as per last annual report.........................	20 507.91
* Increase during the year	$2 537.14

* Of this gain, $1 037.17 is the difference between the par value of the bonds purchased and the amount paid for them.

Report of Committee on Excursions.

Boston, March 18, 1908.

To the Members of the Boston Society of Civil Engineers:

The Committee on Excursions herewith respectfully submits its annual report.

Ten excursions have been made during the past year, as follows:

May 15, 1907. — Concrete Piles at the Milton Car Barns of the Boston Elevated Railway. Attendance, 28.

August 7, 1907. — Turbine Steamer *Yale*. Attendance, 38.

August 22, 1907. — With United States Army Engineers. Inspection of dredgers and Fort Warren. Attendance, 137.

September 7, 1907. — Excursion to Wonderland Park. Attendance, 80.

September 18, 1907. — Inspection of Hassam Pavement laid by Simpson Brothers, in Cambridge. Attendance, 8.

October 19, 1907. — Blue Hill Observatory. Attendance, 42.

October 29, 1907. — Inspection of concrete buildings built by Benj. Fox for the Boston Woven Hose and Rubber Company, Cambridge. Attendance, 40.

November 15, 1907. — Fore River Ship Building Company. Attendance, 50.

December 18, 1907. — Inspection of concrete buildings of Robb-Mumford Company and Richard H. Long Company, at South Framingham. Attendance, 12.

February 19, 1908. — Inspection of work on the Lawrence and Wiggin Wharf at Charlestown. Attendance, 5.

Total attendance, 440; average attendance, 44.

Thirty-two and one-half pages of the *Bulletin of New Engineering Work* and seven pages of *Personal Notes*, or a total of thirty-nine and one-half pages, have been published during the past year, as against thirty-six pages for the previous year.

There is a cash balance of $18.90 in the hands of the Treasurer.

The committee wishes to thank all those who have aided in this work and to express its wish that members at all times will be free to send suggestions for excursions and items for the *Bulletin of New Engineering Work* and the column of *Personal Notes*.

Respectfully submitted,

L. Lee Street, *Chairman*,
Eugene E. Pettee,
Clarence T. Fernald,
Laurence B. Manley,
Edmund M. Blake, *Sec'y and Treas.*

Report of the Committee on the Library.

The annual report of the Committee on Library is herewith submitted:

During the past year there have been added to the library 200 volumes bound in cloth, making a total of 6,258. Of this number 25 were bought, 43 were bound current magazines and 132 were gifts to the Society.

There were 432 volumes in paper added to the library, mainly consisting of reports and bulletins.

An attempt was made, involving considerable labor, to complete our files of town and city reports, and these have now been completed about as far as is practicable. This work was done by one of the members of the committee, and it involved sending out sixty printed requests to the various towns and cities.

The Librarian has felt obliged to enforce the rules regarding fines for books kept overtime and also to disallow the borrowing of books in constant demand, such as those on reinforced concrete, and handbooks such as Kent, Trautwine, etc.

During the year, 155 books have been borrowed from the library.

The committee recommends that the sum of $50 be allowed the coming year for the purchase of current engineering publications.

Respectfully submitted,

FREDERIC I. WINSLOW,
CHARLES SAVILLE,
HERBERT R. STEARNS,
NATHAN S. BROCK,
Committee.

REPORT OF THE COMMITTEE ON ADVERTISEMENTS.

BOSTON, March 18, 1908.

To the Boston Society of Civil Engineers:

The Advertising Committee begs to submit the following report:

At the present time there are 41 advertisements carried in the *Monthly Bulletin*, which yield $910.00 per year, and three advertisements in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES, netting the Society $135.00, making a total revenue for advertisements of $1,045.00 per year.

The amount of advertising carried is somewhat smaller than the amount reported last year. The decrease is due in part to business conditions, but chiefly to the decrease in activity on the part of the Advertising Committee. This lethargy in turn may be explained in part by the fact that with even the present amount of advertising a surplus in the treasury is assured, so that the incentive of last year is now lacking.

It has been suggested by some of the members of the Society that advertising in the *Bulletin* is a species of graft, but it seems to your committee, from the responses which are received from advertisers, that the *Bulletin* is one of the best mediums for certain classes of advertising and, on the other hand, that besides producing a much-needed revenue, the advertising makes the *Bulletin* more attractive.

WILLIAM S. JOHNSON,
S. E. TINKHAM,
F. A. BARBOUR,
Committee.

Montana Society of Engineers.

Butte, Montana, February 8, 1908. — The February meeting of the Society was called to order by Vice-President Chas. H. Bowman, at the usual hour and place. Quorum present. The minutes of the Twenty-First Annual Meeting were approved as read. The application of Worden Irvin Higgins for membership in the Society was read, approved and the regular ballot ordered. Messrs. Tannatt, Kneale, Dearborn, Flaherty, Locke, Sacket and Davis were elected to membership by a unanimous vote. The Secretary read letters from the Montana Congressional Delegation concerning House Bill No. 9230, a bill to establish engineering experiment stations at land grant colleges. The balance of the meeting was devoted to the reading of a paper by the Secretary, written by Ex-President Joseph H. Harper, entitled, " My Impressions of the San Francisco Earthquake." The Society instructed the Secretary to have the paper published in one of the daily papers of the city, thus showing their appreciation of Mr. Harper's thesis.

Adjournment followed.

Clinton H. Moore, *Secretary.*

ASSOCIATION

OF

ENGINEERING SOCIETIES.

VOL. XL. APRIL, 1908. No. 4.

PROCEEDINGS.

Engineers' Club of St. Louis.

ST. LOUIS, MARCH 4, 1908. — The 647th meeting of the Engineers' Club of St. Louis was held at the Club rooms, 3817 Olive Street, on Wednesday evening, March 4, 1908, at 8.30 o'clock, President Brenneke in the chair. There were present thirty-one members and five visitors.

The minutes of the 646th meeting were read and approved.

The minutes of the 438th meeting of the Executive Committee were read.

The Secretary read a letter from Mr. B. W. Frauenthal, secretary of the St. Louis Railway Club, announcing that 250 copies of the Proceedings of that organization, containing Professor Breckenridge's article on "How to Burn Bituminous Coal without Smoke," had been sent to the Engineers' Club for distribution. On motion of Mr. William H. Bryan, duly seconded, it was unanimously voted to extend the thanks of the Engineers' Club to the Railway Club for this courtesy.

A letter from Mr. C. D. Purdon was read, announcing the death of Mr. James Dun, a member of the Club. The President appointed Messrs. C. D. Purdon and J. F. Hinckley a committee to draw up a memorial to be presented at the next meeting.

The following were elected: Bunton, Fred L. (member); Bulkeley, Rolla C. (member); Wyld, Robert H. (member); McCully, William J. (associate member); Burgess, Harold C. (junior member).

It was announced that the complimentary dinner to Mr. M. L. Holman, in recognition of his election to the presidency of the American Society of Mechanical Engineers, would be held on Saturday evening, March 7, at the Missouri Athletic Club.

The paper of the evening on "Timber Preservation" was presented jointly by Messrs. A. L. Kamerer and E. B. Fulks. Mr. Kamerer first presented a paper describing the different methods in use for preserving timber, especially railway ties, and Mr. Fulks followed with a large number of slides illustrating various preserving plants in various parts of the United States and Europe.

A discussion that followed was participated in by Messrs. R. H. Phillips, A. P. Greensfelder, E. B. Fulks and others.

Adjournment.

A. S. LANGSDORF, *Secretary.*

St. Louis, March 7, 1908. — Special. On the evening of March 7, 1908, the Engineers' Club of St. Louis tendered a complimentary dinner to Mr. Menard Lefevre Holman, in recognition of his election to the presidency of the American Society of Mechanical Engineers. The dinner was served at the Missouri Athletic Club, Fourth Street and Washington Avenue, at 7.30 P.M., the total attendance being fifty-four, including members of the Club and representatives of the three national societies of Civil, Mechanical and Electrical Engineers. In the absence of President W. G. Brenneke, who was compelled to be out of the city, Vice-President E. E. Wall presided as toastmaster.

After an enjoyable repast, regular toasts were responded to as follows: Introductory Remarks, the Vice-President, Mr. E. E. Wall; Response, for the Engineers' Club of St. Louis, Mr. W. A. Layman; Response, for the Civil Engineers, Mr. Robert Moore; Response, for the Electrical Engineers, Col. E. J. Spencer; Response, for the Washington University, Dr. C. M. Woodward; "Our Guest," Mr. M. L. Holman.

At the conclusion of the regular toasts, Mr. B. H. Colby, Mr. R. S. Colnon, and Mr. S. Bent Russell responded informally when called upon for remarks.

The meeting adjourned at about 11 P.M., after a thoroughly enjoyable evening. A. S. Langsdorf, *Secretary.*

St. Louis, March 18, 1908. — The 648th meeting of the Engineers' Club of St. Louis was held at the Club rooms, 3817 Olive Street, on Wednesday evening, March 18, 1908, at 8.30 o'clock, Vice-President E. E. Wall in the chair. There were present about thirty members and visitors.

The minutes of the 647th meeting were read and approved.

The minutes of the special meeting of March 7, the complimentary dinner to Mr. M. L. Holman, were read and approved.

The minutes of the 439th meeting of the Executive Committee were read.

The Secretary read the report from Messrs. Holman and Pitzman, delegates to the Joint Conference on Charter Revision, to the effect that it had been decided to ask for a new charter for the city, the present one being out of date and inadequate; on motion, duly seconded, the report was ordered filed.

The Secretary read a letter from the St. Louis Chemical Society transmitting resolutions regarding continuance of the Fuel Testing Plant at St. Louis, and on motion of R. H. Phillips, duly seconded, it was referred to the Committee on Fuel Testing Plant.

There were no reports from Messrs. Purdon and Hinckley, committee appointed to draw up resolutions on the death of James Dun, and they were granted further time.

The following applications were received: Cameron, Bruce (associate member); Burgess, Joseph E. (member).

No other business appearing, the paper of the evening, on the "Fire Resisting Qualities of Building Stone," was presented in a very able manner by Prof. W. E. McCourt, of the Geological Department of Washington University. Mr. McCourt treated the subject in a most thorough and capable manner, giving a preliminary talk on the classification of

stones and the characteristics of a good building-stone, and continuing by giving the result of numerous experiments on the building stones of New York, New Jersey, Wisconsin, Michigan, Illinois and Missouri which had been made by him at various times. A number of stereopticon views showing the effects of heat upon these stones, and views of the effect of the Baltimore fire on building stones were interspersed through the discourse.

The discussion that followed was participated in by various members.

H. E. Grimm, *Secretary pro tem.*

St. Louis, April 1, 1908. — The 649th meeting of the Engineers' Club of St. Louis was held at the Club rooms, 3817 Olive Street, on Wednesday evening, April 1, 1908, at 8.30 o'clock. President W. G. Brenneke in the chair. There were present thirty-eight members and eight visitors.

The minutes of the 648th meeting were read and approved.

The following applications were presented: Wilbur, Ralston Thornton (member); Schueddig, Edward (associate member).

The following were elected: Burgess, Joseph E. (member); Cameron, Bruce (associate member).

It was announced that Colonel Sears of the United States Engineers' Office had presented to the Club Library a set of 157 volumes of the Reports of the Chief of Engineers, United States Army, dating from 1866. The Secretary announced that the donation had been properly acknowledged.

There being no further business, the paper of the evening on Settling Basins 7 and 8, Chain of Rocks, was presented jointly by Mr. G. G. Black and Mr. A. P. Greensfelder. Mr. Black described the basins, which are of reinforced concrete, from the standpoint of their design and gave numerous figures relating to the stresses allowed in different parts of the structure. Detail points of design were illustrated by numerous lantern slides. Mr. A. P. Greensfelder then gave a description of the methods used in the actual construction work, illustrating by lantern slides made from photographs taken as the work progressed.

The discussion which followed was participated in by a considerable number of those present.

Adjourned.

A. S. Langsdorf, *Secretary.*

Boston Society of Civil Engineers.

Sanitary Section.

A special meeting of the Sanitary Section was held at the Boston City Club, Wednesday evening, April 1, 1908. Mr. W. S. Johnson, Chairman, presided, forty-six members and guests being present.

The recommendations contained in the annual report of the Executive Committee, presented by Mr. A. T. Safford, the retiring Chairman, were considered, and upon motion of Mr. Leonard Metcalf, it was voted to authorize the Chairman to appoint a committee of five to consider the

subject of Uniform Specifications for the Manufacture of Vitrified Sewer Pipe; the committee, if it finds it infeasible for the Section to adopt such specifications, to so report. The Chairman has appointed as this committee: Messrs. Leonard Metcalf, F. A. Barbour, L. D. Thorpe, E. S. Dorr and Charles R. Felton.

The following report of the Committee on Uniform Sewerage Statistics was submitted:

BOSTON, MASS., April 1, 1908.

MR. WILLIAM S. JOHNSON,
Chairman, Sanitary Section, Boston Society of Civil Engineers:

Sir, — The Committee on Uniform Sewerage Statistics appointed by you at the annual meeting of the Section on March 4, 1908, presents the following report:

This committee was asked to undertake the work of collecting statistics relative to sewerage and sewage disposal in the various cities throughout this part of the country, and to arrange the data obtained in such form that it would be of value to engineers and city authorities.

It was found that considerable work in this connection had already been done by the present chairman of the Section, and that the information obtained, which was for the year 1906, had been tabulated. An examination of these tables has shown them to be of considerable interest. The committee has made some slight changes in their arrangement and has also attended to the work of reviewing and editing which would be necessary before they could be printed.

In view of the fact that the statistics thus far obtained will be useful to engineers in general, as well as to the members of this Section, we suggest that the main Society be requested to authorize the Section to have this table and similar tables which shall be prepared for subsequent years printed in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES. It is also desirable that extra copies be published for distribution among those who do not receive the JOURNAL, but whose coöperation it is desired to secure.

The committee is now at work collecting statistics from as many cities as possible for the year 1907 to be tabulated in a similar manner to those obtained for the previous year.

Respectfully submitted,

HARRISON P. EDDY.
BERTRAM BREWER.
C. SAVILLE.

Upon motion of Mr. Charles W. Sherman, it was voted to accept the report and adopt the recommendations of the committee. The clerk was instructed to request the early publication of the report, together with the tabulated information which the committee has obtained, in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES, and to request that extra copies be furnished for the use of the committee.

Mr. George R. King gave a very interesting talk upon Alaska, illustrated by a large number of lantern slides. The meeting tendered a vote of thanks to Mr. King.

IRVING T. FARNHAM, *Clerk*.

BOSTON, MASS., APRIL 15, 1908. — A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.30 o'clock P.M., President Joseph R. Worcester in the chair. One hundred and sixty-four members and visitors present.

The record of the last meeting was read and approved.

Messrs. David R. Bates, Austin Cary, James H. Eaton, John A. Garrod, Timothy Guiney, Henry M. McCue, Frederic L. Murray, Edgar A. Norwood, Charles C. Turner and Howard E. Whiting were elected members of the Society and Mr. J. Howard Hayes was elected an associate.

The Secretary announced that under authority of a vote passed at the annual meeting the President had appointed the following special committee to consider the matter presented to the Society in the communication of Mr. Cowles, in relation to increase of membership and clubhouse: L. S. Cowles, G. A. Carpenter, C. R. Gow, R. E. Curtis and C. B. Breed.

The Secretary reported for the Board of Government that under authority of the vote referring to the Board, with full powers, the continuation and appointment of the several special committees of the Society the Board had voted to continue the Committees on Excursions, on the Library and on Quarters, and to discontinue the Committee on Advertisements. The committees as appointed are as follows: —

On Excursions. E. E. Pettee, E. M. Blake, L. B. Manley, R. W. Loud and J. A. Starr.

On the Library. F. I. Winslow, N. S. Brock, W. T. Barnes, M. T. Cook and H. A. Varney.

On Quarters. Desmond FitzGerald, E. W. Howe, G. A. Kimball, F. W. Dean and F. W. Hodgdon.

The Board also appointed the following to represent the Society on the Board of Managers of the Association of Engineering Societies, in addition to the Secretary who is *ex-officio* a member: Dexter Brackett, C. W. Sherman, G. A. Kimball, H. P. Eddy and A. T. Safford.

The Secretary also reported for the Board that it recommended to the Society that the sum of $50 be appropriated for the use of the Committee of the Sanitary Section on Run-Off of Sewered Areas. The report was accepted and on motion of Mr. Johnson, it was voted, That the Sanitary Section be authorized to expend a sum not exceeding $50 for the work of the Committee of the Section on Run-Off of Sewered Areas.

Mr. George A. Nelson, for the committee appointed to prepare a memoir of Alfred E. Nichols, a member of the Society, presented and read its report.

The President announced the death of William Vaughan Moses, a member of the Society, which occurred on April 14, 1908. By vote the President was requested to appoint a committee to prepare a memoir. The President has appointed as the committee, Prof. Frank L. Kennedy.

The Secretary read a communication from the Chamber of Commerce of Pittsburg urging early action by the Society approving the calling of a conference by the President upon the subject of the Conservation of the Natural Resources of the United States. After a brief discussion and the passage of a vote expressing the approval of the meeting of the proposed investigation of the subject, it was voted to refer the communication to the Board of Government with full power for action.

Mr. Cowles for the committee appointed to consider the question of larger membership and a clubhouse submitted a brief report stating that

the committee would not be able to investigate the subject and report its findings before the regular meeting in October next and inasmuch as the present lease of the Society's rooms expires on June 1, it recommended that the same be renewed for one year, with the privilege of further annual renewals, if possible. On motion of Professor Swain the report was accepted and the recommendation adopted.

The President announced that he should endeavor to call the meetings to order promptly at the hour stated in the notice.

Prof. George F. Swain then spoke informally on some points in connection with the Quebec Bridge, illustrating his remarks with a large number of lantern slides. A discussion followed in which Messrs. Cowles, Fay, L. J. Johnson, F. B. Sanborn, J. P. Snow and others took part.

Adjourned.

S. E. Tinkham, *Secretary.*

Montana Society of Engineers.

Butte, Mont., March 14, 1908. — The regular meeting of the Society for the current month was held in Room 16, 225 North Main Street, at 8 p.m. Vice-President Charles H. Bowman presided.

Minutes of previous meeting read and approved.

Mr. W. I. Higgins was elected to membership.

Mr. Robert H. Lindsay, Jr., presented a written protest against the manner of administration and interpretation of Mining Laws on Forest Reserves and, on motion, the paper was referred to the Committee on Revision of Mining Laws.

The Secretary read a paper by Mr. Joseph H. Harper entitled "Aftermath of the San Francisco Earthquake."

The Secretary was instructed to have the paper published in one of the daily papers of the city.

Adjournment followed.

Clinton H. Moore, *Secretary.*

Technical Society of the Pacific Coast.

Regular Meeting held March 20, 1908, at Jules' Restaurant, 328 Bush Street, where the members of the Society assembled at 6.30 o'clock for dinner.

After dinner President George W. Dickie called the meeting to order.

The Secretary read the minutes of the last regular meeting, and of the last Directors' meeting, which were approved.

Mr. Heinrich Homberger read a paper, which he illustrated by lantern slides, entitled "Pressure Fluctuations in Turbine Pipe Lines," which was discussed by Mr. Doble and by the President, who referred to his experiences of past years in relieving the Comstock mines of the accumulated water.

Mr. Homberger's paper was ordered to be sent to the Journal of the Association for publication.

The President referred to the matter that had been suggested in

reference to the cleaning of the city, and to the advisability of donating from the funds of the Society the sum of $250 for this purpose. This caused a general discussion, the opinion being somewhat divided as to the propriety of taking from the limited means of the Society an amount as large as $250.

While some of the members expressed the opinion that no money should be devoted to this end, more of them seemed in favor of setting aside a smaller amount, more in keeping with the limited possessions of this Society.

Professor Kower thereupon moved that it be the sense of this meeting that the sum of $100 be donated to the Citizens Committee for the purpose of cleaning San Francisco, and that in addition to this donation the members be called upon individually to contribute and that these contributions be forwarded to the committee.

The underlying idea of this motion being this: That most members will prefer an individual donation rather than that the funds be drawn upon to the extent originally proposed.

The meeting thereupon adjourned.

OTTO VON GELDERN, *Secretary.*

Detroit Engineering Society.

DETROIT, MICH., MARCH 27, 1908. — One hundred and eighth regular meeting.

Meeting called to order at 8.10 P.M., President E. S. Wheeler presiding.

Minutes of the 107th regular meeting, of February 28, read and approved.

Mr. A. Geo. Mattsson gave notice that an amendment to the constitution was necessary to make any one an Honorary Member.

The President gave notice that the men appointed to get the speakers for the annual banquet were as follows: Benj. Douglas, Alex. Dow, and Walter Russel.

Moved by W. R. Kales, seconded by B. E. Parks, that the President name the nominating committee for the annual meeting.

Discussion in regard to raising the annual dues from $5 to $6; Messrs. Keep, Blauvelt, Shenehon, Mattsson, etc., took part in the discussion.

Moved in amendment by W. S. Blauvelt, seconded by B. E. Parks, that the annual dues of those that take the JOURNAL be $6 and those that do not take JOURNAL be $5: discussion by Keep, Fenkell, Shenehon, Kales, Mattsson, Parks, etc. Mr. W. S. Blauvelt, with the permission of Mr. B. E. Parks, withdrew his amendment.

Motion to raise dues from $5 to $6. Carried.

Moved by Mr. T. McCrickett, seconded by W. S. Blauvelt, that the Executive Committee define the number of complimentary tickets that each member is entitled to for the annual excursion.

The following candidates were declared elected, Wright B. Thompson, C. F. Coda, A. C. Bornholt.

The paper of the evening was then presented by E. S. Wheeler, on "The Estimated Cost of Building a Pyramid in Detroit Similar to the Great Pyramid of Gizeh." Discussion followed.

Moved by F. C. Shenehon, seconded by G. H. Fenkell, that the paper be printed in the JOURNAL. Carried.

Moved by B. E. Parks, seconded by A. G. Mattsson, that we adjourn. Carried.

BAMLET KENT, *Secretary.*

DETROIT, MICH., APRIL 10, 1908. — Special meeting of the Detroit Engineering Society. Meeting called to order at 8.10 P.M, Second Vice-President A. L. Colby in the chair.

The paper of the evening on "Gas Engines and Gas Producers," with stereopticon views of the various parts, was presented by V. E. McMullen, of the Fairbanks Morse Manufacturing Company, Beloit, Wis. The paper was discussed by the following: Fenkell, Mason (Jackson), Lane, Kales, Collamore, Barthel, Shenehon, Blodgett, Mason (Detroit), Vorce, etc.

Meeting adjourned at 10.20.

BAMLET KENT, *Secretary.*

Association of Engineering Societies.

Vol. XL. **MAY, 1908.** No. 5.

PROCEEDINGS.

Engineers' Club of St. Louis.

St. Louis, April 15, 1908.—The 650th meeting of the Engineers' Club of St. Louis was held at the club rooms, 3817 Olive Street, on Wednesday evening, April 15, at 8.30 o'clock. President W. G. Brenneke presided. There were present forty-two members and five visitors. The minutes of the 649th meeting were read and approved. The minutes of the 440th meeting of the Executive Committee were read.

The following were elected: Ralston Thornton Wilbur, member; Edward Schueddig, associate member.

The committee, consisting of Messrs. J. F. Hinckley and C. D. Purdon, appointed to draw up a memorial of the late Mr. James Dun, submitted its report.

It was voted that the memorial be spread upon the records and printed in the Journal,* and that a copy be sent to Mr. W. B. Story, chief engineer of the Santa Fé system, for presentation to Mrs. Dun.

The resolutions drawn up by the St. Louis Chemical Society in regard to the continuance of the fuel testing plant having been referred to the Committee on Fuel Testing Plant, with a request that some recommend-a tion be made, the committee, through its chairman, Mr. Edward Flad, submitted a report recommending that no action be taken until after the conference called by President Roosevelt on the "Conservation of the Natural Resources" at the White House, May 13, 14, 15, 1908.

There being no further business, the President announced that the program of the evening, a discussion of the "Conservation of the Natural Resources of the United States," was in order, and called upon Mr. M. L. Holman to open the discussion. In his remarks Mr. Holman outlined the plan and scope of the conference to be held in Washington in May, and stated that the work of the conference would probably be along quite general lines. He showed that the whole matter was largely one involving the question of states' rights, and in some cases of international policy, so that much of the work to be done would have to be settled by the courts. But he also stated that there would be a large field for engineers in determining the economic features of work to be undertaken.

* See Journal for April, 1908, page 241.

Col. J. A. Ockerson, having been compelled to be out of the city, submitted a written discussion, which was read by the Secretary. Mr. Ockerson confined himself principally to a discussion of the effect of forest growth upon rainfall and river floods, showing that there was much misinformation on this subject requiring correction. It is practically certain that forests have no effect upon the rainfall, their real value residing in their ability to check the rapidity of the run-off and in preventing erosion.

Mr. Robert Moore discussed the subject of the "Conservation of the National Health," and advocated the establishment of a national bureau of health, one of whose duties would be a systematic collection of vital statistics now almost altogether neglected, especially by the Central, Western and Southern states.

Prof. J. L. Van Ornum spoke of the great importance of preserving the purity of our water supply, and advocated the adoption of systems of sewage purification before its discharge into the rivers.

Mr. William H. Bryan presented a general synopsis of the entire subject, dealing with the subjects of fuel and mineral supply, and proper care of sands and soils and the utilization of natural sources of power.

Mr. C. D. Purdon presented some statistics on the timber supply and stated that different writers estimated that the present available supply of timber would be exhausted in from fourteen to thirty years.

Mr. A. S. Langsdorf stated that the whole subject of conservation of natural resources was very thoroughly discussed in a book called "Man and the Earth," by the late Prof. Nathaniel Shaler, of Harvard University.

The discussion was then brought to a close by Mr. Holman, who gave a brief statement of the probable attitude of the engineering representatives at the forthcoming White House conference.

Adjourned.

A. S. Langsdorf, *Secretary.*

St. Louis, May 6, 1908. — The 651st meeting of the Engineers' Club of St. Louis was held at the Club Rooms, 3817 Oliver Street, on Wednesday evening, May 6, at 8.30 o'clock, President W. G. Brenneke presiding. There were present twenty-three members and thirteen visitors.

The minutes of the 650th meeting were read and approved.

The minutes of the 441st meeting of the Executive Committee were read.

The Secretary read a letter from Mr. C. A. Bulkeley, chairman of the Entertainment Committee, announcing the plans for a series of excursions to be given before the summer recess.

The paper of the evening on "Aids in Railroad-Bridge Designing" was then presented by Mr. S. W. Bowen. Mr. Bowen had prepared a number of charts for the ready determination of such data as moments, shears, economic depths and weights of various forms of trusses, through and deck girders. The charts were prepared for the purpose of minimizing the computations in the design of trusses and floor-beams for any loading and any span, and furnished an excellent illustration of the value of the graphical method. The paper was discussed by Messrs. J. L. Jacobs, E. B. Fay and A. S. Langsdorf.

Adjournment.

A. S. Langsdorf, *Secretary.*

Montana Society of Engineers.

Butte, Mont., April 11, 1908. — The Society meeting for April was called to order at 8 P.M. by Vice-President Bowman. Minutes of March meeting approved as read The applications of Messrs. Hayes, Leggat and Hoffman for membership were presented and on approval the necessary ballots were ordered. The matter of a midsummer meeting was given considerable attention and the Board of Trustees, to whom the subject was referred at the last annual meeting, were invited to present a report at the May meeting of the Society upon the feasibility of holding such a meeting and to suggest a suitable date for the same. The Secretary read a communication from the Chamber of Commerce, Pittsburg, Pa., having for its subject the letter of President Roosevelt inviting the governors of the states and members of Congress to a conference at the White House next May to consider the subject, the "Conservation of the Natural Resources of the United States." The Chamber of Commerce requested the approval of the President's action by this Society if in accord with its views, and on motion the following was adopted:

Whereas, The Montana Society of Engineers, in their business and professional relations with the great industrial enterprises of the country, realize the pressing needs for preserving, correcting abuses and economically using the natural resources of the country; therefore be it

Resolved, That we earnestly request the Governor of Montana and the Senators and Representatives of this state in Congress to attend the conference called by the President of the United States at the White House, May 13–15, 1908, and labor in every way to promote its success; and be it further

Resolved, That the Secretary of this Society send a copy of these resolutions to the Governor of this Commonwealth and the Congressional Delegation of Montana.

Ex-President Kinney gave a talk on some interesting features of an irrigation project under his present supervision in Gallatin County. Mr Goodale reported progress for the Committee on the Revision of Mining Laws.

Adjournment.

Clinton H. Moore, *Secretary*.

The Detroit Engineering Society.

Detroit, Mich., April 17, 1908. — Fourteenth annual meeting of the Detroit Engineering Society.

Meeting called to order by the President at 7.45 P.M

Minutes of the 108th regular meeting read and approved.

Minutes of special meeting of April 10, 1908, read and approved

Moved by Mr. G. S. Williams, seconded by Mr. S. G. Barnes, that the Secretary be instructed to cast one ballot for Mr. Francis C. Shenehon for President for the coming year. Carried

Moved by Mr. Walter S. Russel, seconded by F. P. Johnson, that the Secretary be instructed to cast a ballot for Byron E. Parks for first Vice-President for the coming year. Carried.

Moved by D. M. Mason, seconded by Geo. L. Grimes, that the Secretary be instructed to cast a ballot for Chas. G. Herbert for second Vice-President for the coming year. Carried.

Moved by W. R. Kales, seconded by D. M. Mason, that the President be instructed to cast one ballot for Bamlet Kent for Secretary for the coming year. Carried.

Moved by Benjamin Douglas, seconded by W. R. Kales, that we adjourn to the Hotel Tuller for the annual banquet. Carried.

At the hotel there were one hundred and twenty-three who sat down to the annual dinner, after which Mr. E. S. Wheeler, the retiring President, turned the meeting over to Francis C. Shenehon, the newly elected President, to act as toastmaster. Speeches, etc., were received from Gardner S. Williams, chairman of the Managing Board; Mr. A. F. Nock, Col. C. McD. Townsend, Walter S. Russel, A. Geo. Mattsson and Bingley R Fales. Mr. Bernard Nagelvoort gave several musical selections.

Meeting adjourned at 12.40 A.M.

BAMLET KENT, *Secretary*.

Association of Engineering Societies.

Vol. XL. **JUNE, 1908.** No. 6.

PROCEEDINGS.

Engineers' Club of St. Louis.

St. Louis, May 20, 1908. — The 652d meeting of the Engineers' Club of St. Louis was held at the Club rooms, 3817 Olive Street, on Wednesday evening, May 20, 1908, President Brenneke presiding. There were present thirty-eight members and one visitor.

The minutes of the 651st meeting were read and approved, and the minutes of the 442d meeting of the Executive Committee were read.

The Secretary presented an application for Associate Membership, received from Mr. Oliver B. Barrows.

Mr. A. O. Cunningham, chief engineer of the Wabash Railroad, presented the paper of the evening on " Engine Terminal Facilities Constructed by the Wabash Railroad at Decatur, Ill." Mr. Cunningham described in detail the construction of the roundhouse and the facilities for watering and coaling locomotives, of which about one hundred are handled each day; itemized costs of various parts of the installation were given and the structural details were illustrated by a large number of lantern slides.

Adjournment.

A. S. Langsdorf, *Secretary.*

Boston Society of Civil Engineers.

Boston, Mass., May 20, 1908. — A regular meeting of the Boston Society of Civil Engineers was held in Chipman Hall, Tremont Temple, at 7.30 o'clock p.m., President J. R. Worcester in the chair, seventy-eight members and visitors present.

The record of the last meeting was read and by vote approved.

Mr. Erasmus D. Leavitt was elected an honorary member, and Messrs. Charles F. Breitzke, Maurice F. Brown, Howard L. Coburn, Arthur W. Emerson, George F. Hobson, Arnold Seagrave, Arthur E. Tarbell, Ernest M. Trefethen and Joseph F. Wilber, members of the Society.

The President reported for the Board of Government, in the matter referred to it at the last meeting, in relation to the proposed conference in the conservation of the natural resources of the country, that it had invited Prof. George F. Swain to represent the Society at that conference so far as an opportunity presented itself and to express the approval of the Society as shown by the vote at the last meeting.

The Secretary read a communication from the Mayor of Boston calling attention to an act of the Legislature of 1907 authorizing the mayor to appoint a member of the Board of Appeal, the member so appointed to be selected from "two candidates, one to be nominated by the Boston Society of Architects and one by the Boston Society of Civil Engineers." On motion of Professor Allen, the communication was referred to the Board of Government with full power.

Prof. F. L. Kennedy, the committee appointed to prepare a memoir of our late associate, William V. Moses, submitted and read his report.

Mr. James E. Howard, civil engineer, read the paper of the evening entitled, "Some Causes which Tend Toward the Fracture of Steel Rails." The paper was illustrated by lantern slides.

The Secretary read, in the absence of its author, a discussion on the subject of the paper by Mr. J. Parker Snow. Further discussions were offered by Prof. Henry Fay, of the Massachusetts Institute of Technology; by Mr. Wm. A. Aiken, of New York, and Mr. George A. Kimball, chief engineer, and Mr. H. M. Stewart, road master, Boston Elevated Railway Company.

Adjourned.

S. E. TINKHAM, *Secretary.*

Montana Society of Engineers.

BUTTE, MONT., MAY 8, 1908.—The regular meeting of the Society for the current month was held in the Society room at the appointed hour. Vice-President C. H. Bowman presided. Quorum present. Minutes of last meeting approved. Messrs. Hayes, Leggat and Hoffman were elected by the regular ballot to active membership in the Society. The Secretary was instructed to write Mr. Martin H. Gerry, Jr., and invite him to furnish the Society with a paper on the construction of the dams at Wolf Creek and at Hauser Lake. On motion, the Secretary was urged to procure an opinion from the Trustees as to the advisability of holding a midsummer meeting of the Society and present the same at the next meeting.

Adjournment.

CLINTON H. MOORE, *Secretary.*

Technical Society of the Pacific Coast.

REGULAR MEETING, June 5, 1908, called to order at 8 o'clock by President George W. Dickie.

The meeting was held at the New Tortoni Restaurant, 1400 Polk Street, where the members assembled for dinner at 6 o'clock. After dinner the business of the Society was taken up.

The Secretary read the minutes of the last regular meeting, held on March 20, 1908, and upon motion the minutes of this meeting were duly approved as read.

Mr. Heinrich Homberger proposed for membership, Mr. J. W. White, mechanical engineer, care of Engineering and Maintenance Company, Fremont and Howard streets, San Francisco. It was ordered that this application take the usual course; the Secretary was instructed to communicate with Mr. White and to send him the necessary blanks.

Mr. H. D. Connick read a very exhaustive paper containing the substance of a municipal engineering report on the subject entitled, "The Auxiliary Water Supply of San Francisco." This paper proved a very interesting and important one, and on account of the lateness of the hour the President suggested that all discussion be waived and that the subject be taken up again for discussion at the next regular meeting; also, that five members be appointed, chosen from among those more particularly versed in this subject, and that these members so chosen prepare written discussions to be presented to the Society at the next regular meeting in August.

This suggestion was put into the form of a motion and unanimously carried.

The appointment of the committee of five will be taken up by the President after considering the available members for that purpose.

The meeting thereupon adjourned.

Otto von Geldern, *Secretary.*

JOURNAL

OF THE

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July to December, 1908.

PUBLISHED MONTHLY BY

Fred. Brooks, Secretary of the Board of Managers of the Association of Engineering Societies.

31 Milk Street, Boston.

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ABBREVIATIONS. — D. = Discussion; I. = Illustrated.
Names of authors, etc., are printed in *italics*.

ASSOCIATION
OF
ENGINEERING SOCIETIES.

Organized 1881.

VOL. XLI. JULY, 1908. NO. 1.

ABOLITION OF GRADE CROSSINGS IN THE CITY OF NEW BEDFORD.

BY WILLIAM F. WILLIAMS, MEMBER OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read before the Society March 18, 1908.]

THE first step towards securing the abolition of grade crossings in New Bedford was taken in 1893 by the employment of Mr. John D. Fouquet, a civil engineer of New York City, to examine the situation and report his recommendations. He advised that the streets be carried over the railroad. In 1894 the mayor and aldermen petitioned the Superior Court for the appointment of a commission to examine and report upon the best method of abolishing practically all of the main line crossings. The commission was appointed that same year, and in 1903 they made a report which was later recommitted for further consideration, the final report being signed December 21, 1905, and confirmed by the court, October 9, 1906.

It would be impossible, within the limits of this article, to go into the details of this long-drawn-out controversy. I shall therefore only briefly touch on those matters that are essential to an intelligent statement of the scheme as now being carried out.

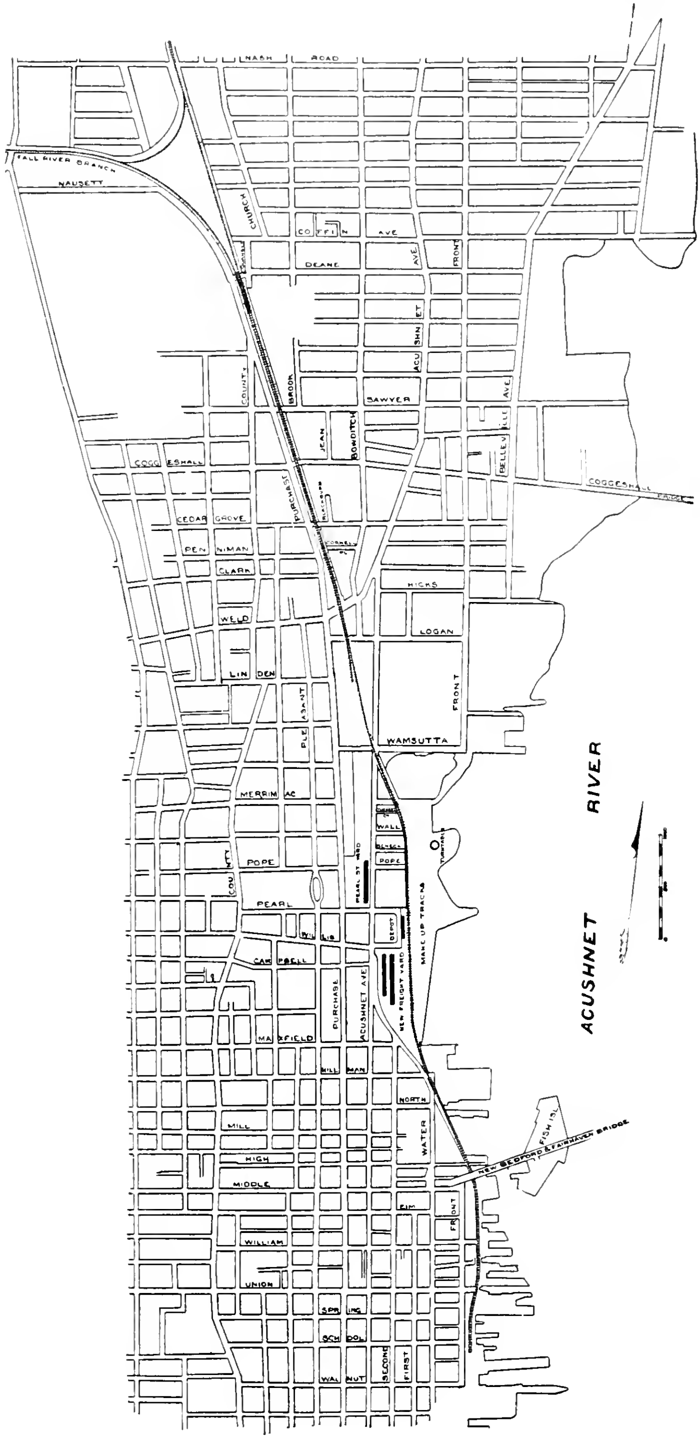
The petition of 1894 named the 16 crossings from Nash Road to the terminus of the line at the foot of School Street, a distance of about $2\frac{1}{3}$ miles. From the passenger station south for about 4 000 ft. the tracks adjoin the water front, and of the crossings named, 8 were in this section.

Of these water front crossings, that of the approach to the bridge to Fairhaven was the most important. In point of fact, it might be said to have been the inspiring cause of the petition. The legislature of 1893 had authorized the county commissioners to build a new bridge, and, if they saw fit, to petition for the abolition of the grade crossing at its approach. They decided, however, to widen the bridge at grade, and later commenced its construction on those lines. A public meeting was held about this time at which the proposed action of the commissioners was strongly denounced. Without doubt, public opinion, as far as shown by open expression of views, was in favor of eliminating the bridge crossing by carrying the approach to the bridge over the railroad. Yet it was evident that if an overhead bridge was built, the crossings south of this point could not be altered, inasmuch as there was not enough room between the railroad and the water to elevate the crossings. The construction of an overhead bridge would make it impossible to elevate the railroad, and the presence of tide water would prevent the railroad from being depressed.

In 1896 the bridge was widened and laid out at grade, with hardly a remonstrating voice, but when, in 1899, it was proposed to commence the construction of the New Bedford end of the bridge at grade, public opinion was again aroused in favor of an overhead structure. In 1900, after a long and very bitter controversy, an act was passed by the legislature which took the construction of the bridge out of the hands of the county commissioners and placed it in the city of New Bedford, with the approval of the railroad commissioners and the harbor and land commissioners. This led to the completion of the bridge as an overhead structure in 1902.

As soon as this act was passed, the city withdrew so much of its original petition as referred to the bridge crossing and those south of it. Therefore the final report of the Grade Crossing Commission dealt only with the crossings north of the bridge.

After several years, with many hearings and much discussion, it was decided by the Grade Crossing Commission that the general scheme of alteration should be to elevate the railroad about 14 ft. and depress the streets about 4 ft. The low rate of grade of the crossings and of the streets directly connected with the same made it impossible to carry the streets over the railroad without excessive grades, and within a reasonable limit of cost. The proximity of tide water, together with the underlying granite formation, precluded the depression of the railroad. It was also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JEAN
BOWDITCH
BELLEVILLE
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CLARK
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LOGAN
LINDEN
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PEARL
MAKE UP TRACKS
ACUSHNET
WILLIS
DEPOT
CAMPBELL
NEW FREIGHT YARD
PURCHASE
ACUSHNET AVE
MAXFIELD
HILLMAN
NORTH
FISH ISL
MILL
WATER
NEW BEDFORD & FAIRHAVEN BRIDGE
HIGH
MIDDLE
ELM
FRONT
WILLIAM
UNION
SPRING
SCHOOL
WALNUT
SECOND
FIRST

decided that the Nash Road crossing was not used enough to justify its abolition. Therefore the change in grade of the railroad began at Nash Road and ended at the passenger depot.

May 30, 1903, the commissioners signed a report against which objections were filed in the Superior Court by the attorney-general and the attorney for the railroad on the grounds that in certain details it was contrary to law. The more important of these were that the commission had decided that Weld Street should be widened 30 ft., that a new street should be laid out adjoining the proposed new freight yard, and that Water Street crossing, which was not specifically named in the petition, should be abolished by relocating the railroad. Weld Street not only has the largest amount of traffic of any of the crossings, but its location is such that this traffic is bound to keep pace with the growth of the city. The street was 50 ft. in width and was occupied by one track of the street railway. Incidentally, I will state that our petition was brought before the passage of the law making street railways a party to the cost in grade-crossing proceedings. It was, therefore, impossible to place any part of the cost of abolishing this crossing upon the street railway, although it was apparent that it was to be very largely benefited by the widening and abolition. It will now have a double track and continuous operation, where formerly it had a single track with many interruptions. By the consent of all concerned, the report was referred back to the commission.

Shortly after this action, the attorney employed by the city died, and a little later Mr. Horatio G. Herrick, one of the commissioners, died. After these vacancies were filled, the questions in dispute were again taken up, and it was finally agreed at a conference with President Mellen that the city should lay out a widening of Weld Street at its own cost, and then no objection would be made to the commission providing for the abolition at its new width. The land required for the widening belonged to the Old Colony Railroad and the Union Street Railway Company, and both corporations gave the same without charge. The difficulty over Water Street was cured by a petition for that one crossing, which was referred to the same commission.

It was also agreed that the street adjoining the freight yard should be taken out of the report and built at the joint expense of the city and railroad; also that the bridges should be supported on steel columns set in the sidewalks near the curb line, and that they should have an open steel floor system with ties covered with 2-in. plank. The report of 1903 called for solid

floor bridges, and limited the use of columns in the sidewalks to the bridges over Weld Street and Acushnet Avenue.

One question in dispute was left for the commission to determine, and that was, Should the city or the railroad do the work in the streets? The commission decided that the railroad should do the excavation and the city all the rest of the work in the streets.

It is worthy of comment that this is probably the first general grade crossing alteration of any magnitude in this state in which the considerations of necessity and cost were so literally enforced in the plans and report finally adopted by the commission. This was in part due to the disinclination of the railroad to make any changes in the crossings, and in part to the insistence of the attorney-general that the cost must be kept down to the lowest figure compatible with standard railroad practice and a fair substitution for what both the city and the railroad then enjoyed. As a result, the general design is extremely plain, inartistic, and in some respects inadequate. On the other hand, the character of the work is substantial and durable, but the graceful arch of stone, concrete or steel is conspicuous by its absence.

The plan is inadequate in respect to the trackage provided for handling freight. No doubt it is equal to that already in use, but the freight facilities had been wofully insufficient for years. It may seem strange, but it was the representatives of the city who, realizing this situation, endeavored to have it rectified in the plans for the new yard. This was combated both by the state and the railroad, although the work on the alterations had only fairly begun when the railroad officials finally realized that more room was needed and plans were then made for continuing the use of the old Pearl Street yard for certain classes of inward freight.

New Bedford is 57 miles by railroad measure from the South Station, Boston, and is the terminus of the Taunton division of the Old Colony Railroad. It is also the terminus, through the medium of a ferry, of the Fairhaven branch of the same railroad, also of the direct line to Fall River, known as the Wattuppa Branch, a part of the Old Colony System, but all now leased by the New York, New Haven & Hartford Railroad.

The New Bedford & Taunton Railroad was completed to New Bedford in 1840, when the population was 13 000. It is now 90 000. It was a single-track road with four trains a day, two inward and two outward, terminating at Pearl Street in a depot

of very ancient design, the location of which was the subject of a long controversy, one faction favoring a location farther north; but it was decided by vote of the stockholders to locate it at Pearl Street.

In 1873 the railroad was extended along the water front to School Street, about 4 200 ft. south of Pearl Street. The extension diverged from the main line near Logan Street, about 2 500 ft. north of Pearl Street.

In 1886 a new passenger station was built on the extension just south of Pearl Street, and about 400 ft. east of the old station. The old station was soon demolished and freight houses built in its place. Strange to say, the public apparently took no interest in the location of the new depot, and a very attractive building was most poorly located for the convenience of the great majority of the patrons of the railroad. The station should have been built on the water front between Union Street and School Street, where connection was then and is now made with the Nantucket and Vineyard boats, the Cape Line via the ferry, and in the summer with the New York passenger boat.

The railroad enters New Bedford a short distance south of Braley's Station and is double tracked to its terminus, a distance of 7.4 miles. The grade crossing changes, however, are all included within a distance of about 11 000 ft. from Nash Road south. The direction of the railroad is slightly diagonal to the principal north and south streets, although one important thoroughfare, Purchase Street, adjoins it on the west from Weld Street, northerly about 3 200 feet. The most important crossings are Weld Street and Acushnet Avenue.

The cotton mills are nearly all on the water front and about evenly divided north and south of the freight yard. Only one mill in the city has direct rail connection. All receipts and shipments for the other mills are handled by teams.

The crossings abolished by the decree, in their order from the north, are:

Deane Street, 50 feet wide.

Sawyer Street, 50 feet wide.

Weld Street, 80 feet wide.

Logan Street, 50 feet wide.

Wamsutta Street, 45 feet wide, and Acushnet Avenue, 50 feet wide, a combined crossing, and

Water Street, 40 feet wide.

Wall Street crossing is abandoned and Coggeshall Street and Cedar Grove Street are carried under the railroad at the city's ex-

pense, as they were not laid out across the railroad location at the time of the petition.

The change in grade of the railroad begins on the south side of Nash Road, at which point it is about 66 ft. above tide water. It then runs level to Deane Street, where a head-room of 14 ft. is secured to the highway. This crossing is in substitution for the old crossing about 50 ft. further south, known as Purchase Street. From this point the grade follows practically parallel to the old grade at the rate of 0.765 ft. per 100 ft. to Weld Street; it then increases to 1.035 per 100 to Wamsutta Street and then to 1.12 per 100 to elevation 5.3 ft. at the north end of the depot, which is about 1 ft. above the old track level, requiring some readjustment of the station platform, but no change in the building itself.

The Water Street portion of the double crossing at Water and Hillman streets, south of the depot, is abolished by moving the tracks east and taking the old track location for the street. Formerly Water Street crossed the tracks and ended at Hillman Street. Public travel will be removed from this crossing, but travel to the two wharf properties immediately east will continue to cross the tracks at grade.

The elevated tracks are carried on solid fill within retaining walls and abutments of Portland cement concrete, except for short distances where it was possible either to slope within the company's lines or to secure land for the same at less than the cost of a wall.

A single track was first laid on the extreme west side of the railroad location from a short distance north of Deane Street to Weld Street, and all traffic was conducted on this single iron. The east wall and the east half of the abutments for the bridges north of Wamsutta Street were then built.

The material for the fill was brought by train from a gravel bank near Howland's Station, about ten miles north of the site of the work. Here it was loaded into Porter cars by steam shovel and unloaded by a steam plow, which worked rapidly and left the shovelers fresh to promptly clear the gravel away from the train and get the track up to its new grade for the next train. There will be approximately 300 000 cu. yds. of filling placed in the execution of this work.

In the building of the walls and abutments no very serious difficulties were met and good bottom was found without the necessity of using piles. Some very vexing conditions, however, were encountered, as, for instance, wherever the existing surface was above the original surface, as was the case for the most of the

distance south of Sawyer Street. It seemed as though some one with malicious premeditation had completely filled the site of the various foundations with bowlders of all sizes and shapes. Of course these had to be all taken out, because they were not properly laid and there was no knowledge as to the condition of the material under them.

The forms for the retaining walls were built with uprights of 4 in. by 6 in. timbers, the battened sections of the form being secured to these uprights with straps of thin hoop iron. Wedges were then driven between the battens of the form and the uprights to secure a solid connection without using spikes; any slacking of the form could also be easily taken up. The front and back forms were also tied together at intervals with pieces of hoop iron, which later were broken off and left in the concrete. The whole form was well braced from the outside by diagonal struts. The forms were built of boards planed on the inside face and thoroughly cleaned of cement and coated with crude oil before using.

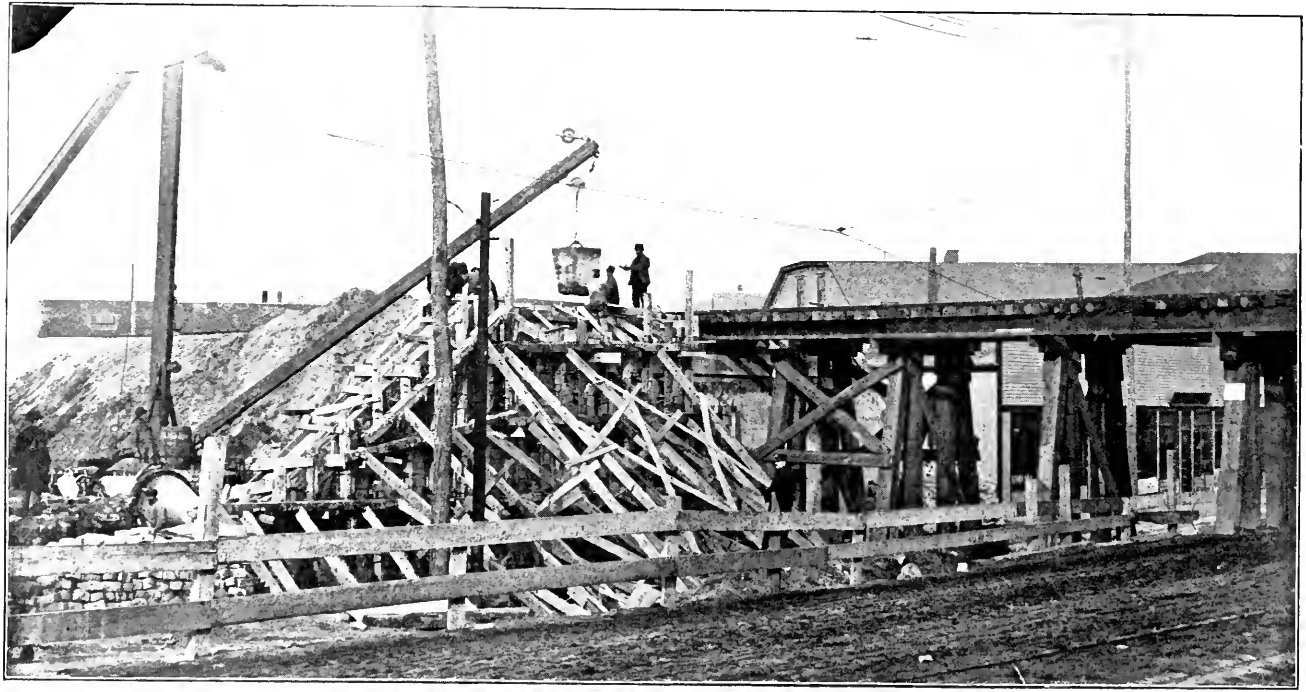
The concrete for all the walls and abutments, except bridge seats and coping, was a 1 : 3 : 5 mixture, made very wet in rotary mixers. The concrete was discharged from the mixer into rectangular bottom dumping buckets, handled by derricks, and dumped where required in the forms with very little placing by hand.

Copings, bridge seats, parapets and pier foundations were made of a 1 : 2 : 4 mixture. Gravel was used almost entirely in all the concrete, and a very liberal latitude was allowed in the variations in size of same. Blocks of granite of all sizes and shapes were bedded in the foundations and upper part of the walls and abutments. The Dragon brand of Portland cement was used throughout this work.

The forms were removed as soon as the concrete had set enough to maintain its shape, generally inside of three days. The face of the concrete was then rubbed by hand with corundum blocks, the surface being kept wet during the operation. Holes of any size were filled with neat cement. The result of this treatment is a smooth surface with all grain marks of the boards and small defects in forms removed. Just how this smooth, blank surface will stand the test of time remains for the future to show.

Expansion joints are made about 60 ft. apart in the walls and one in the middle of the abutments. The west wall north of Weld Street is 7 ft. 2½ in. from the surface of the ground to the

Forms for Concrete Wall on Purchase Street.



Forms for Weld Street Abutment.

under side of the coping, which is 12 in. thick and 2 ft. 6 in. wide, with 3 in. projection. The wall is 6 ft. thick at the base and 2 ft. 6 in. under the coping. The foundation is 6 ft. 3 in. thick and about 4 ft. deep. The projection is on the front. The back of the wall is on a batter, and the face is plumb. The east wall and west wall south of Weld Street is about 15 ft. from surface of ground to under side of coping, the base 9 to 10 ft. in width.

The abutments are 10 ft. 6 in. through the foundations, stepping in one foot on the face at the surface, and are 4 ft. 3 in. thick under the bridge seat, which is 2 ft. 6 in. wide, 18 in. thick, with a 3 in. projection. The face of the abutment is vertical and the back on a batter.

As fast as the east halves of the abutments were completed, single-track timber trestles were erected across the streets and the filling put in place. A single-track timber trestle was also erected from Weld Street to Logan Street, a distance of about 240 ft., as the width of location did not admit of filling one side while operating on the other side.

In order to reduce the stoppage of street-car travel at Weld Street to as short a time as possible the trestle across this street was left out until the fill south of Logan Street and Wamsutta Street was mostly placed by backing the trains up from the south. As soon as the trestle was completed the balance of the fill was placed and then the passenger trains commenced running overhead.

At this time the widened portion of Weld Street had been graded and paved, and the north track of the street railway laid, as far as the single track at grade, which was then being used by freight trains. Team and foot travel was not interrupted at any time on this crossing. Street car travel was stopped November 26; and on Sunday, December 22, freight trains were also run overhead, the single track at grade removed, and at 6 o'clock in the evening the street cars were running under the trestle on the permanent north track.

In every way the Wamsutta and Acushnet Avenue crossing has been the most difficult to construct. Acushnet Avenue, running north and south, crosses Wamsutta Street at about a right angle. Wamsutta Street is 45 ft. wide and Acushnet Avenue is 50 ft. wide. The railroad, however, crosses both streets at a long skew, making an angle of about 28 degrees with Acushnet Avenue. This made it very difficult to arrange the bents of the trestle so that teams could pass through on both streets.

The tracks also cross Wamsutta Street to enter the Pearl

Street freight yard. The decree abolished these tracks, but it has been found necessary to continue the use of the yard, and a single-track overhead bridge will provide an entrance to it. This freight yard is still being operated and has never been closed during the construction.

The grades of both Acushnet Avenue and Wamsutta Street are lowered about 5 ft. and the clear head-room will be $13\frac{1}{2}$ ft. The presence of tide water and a very important sewer made it impossible to lower these grades any more.

The railroad embankment south of Wamsutta Street has natural slopes on both sides, and a natural slope next to the avenue north of this street.

The grade of Wamsutta Street to the west will be 7.5%, but only 1% east of the avenue. The grade of Acushnet Avenue is worked out with 1.2% rate to the north and a 1% rate to the south. It was of the greatest importance to keep the rates on the avenue low on account of the heavy loads hauled and the low rate of grades on this street from the freight depot north.

To provide all the room possible for teams, and because the railroad abuts on the west side of the avenue from Logan Street to Pearl Street, a 9-ft. sidewalk will be built on the east side of the avenue only, and on the north side of Wamsutta Street, east of the avenue. West of the avenue there will be two sidewalks. The sidewalks will have granite curbs and a coal-tar concrete surface. The roadways will be paved with granite blocks laid on a 5-in. Portland cement concrete foundation. A portion of the paving is already laid; in fact it was necessary to do this work as soon as the grading was completed. It was utterly impossible to maintain travel over the graded surface and it was out of the question to cut off the use of the street.

The presence of the track at grade for serving the Pearl Street freight yard, complicated our work in the avenue, so that at one time it was necessary to divert travel through a portion of the freight yard and an old car house. One half of the street was then cut to grade and paved.

The most difficult piece of work in connection with the street changes was the construction of a concrete sewer to take the place of two brick sewers, one of 24 in. diameter in the middle of Acushnet Avenue from Wamsutta Street south, the other of 42 in. diameter, diverging from the sewer in the middle of the avenue north of the crossing and then following the gutter line south. This location conflicted with the foundations of the piers, so both sewers were combined in one in the middle of the

Deane Street Bridge.

street. The grade of the invert of the sewer was fixed by that of the sewers to be connected by the new sewer. This, with the cut in grade at the intersection of the streets, made it necessary to adopt a rectangular section 3 ft. by 7 ft., for a length of 110 ft. This was gradually changed at both ends to a horseshoe section, i. e., a semi-circular arch of 6 ft. diameter on vertical sides, 1 ft. high and a nearly flat bottom. The top of the rectangular section was made 12 in. thick with 8-in. 18-lb. I-beams imbedded therein, spaced 2 ft. 3 in. on centers and tied together with $\frac{3}{4}$ in. rods. The portions connecting the rectangular with the horseshoe section are reinforced with $\frac{1}{2}$-in. round rods, spaced from 6 in. to 9 in. on centers and wired to three $\frac{3}{4}$-in. longitudinal rods, spaced about 2 ft. on centers. The block paving is laid directly on top of the reinforced portions of the sewer. The proportions of the concrete for this work were 1 : 2 : 4 and 1 :3: 5, using Dragon Portland cement. The stone was crushed granite, varying from screenings to stone $1\frac{1}{2}$ in. in diameter. Collapsible wood forms, in 12-ft. lengths, were used and all the work was done by day labor. The old sewer was built on top of marsh mud varying in thickness from 1 ft. to 4 ft., all of which had to be taken out and the space filled with concrete rubble. The invert was built first, about 48 hours ahead of placing the form for the sides and arch. The forms were only allowed to stand over night, but we had no trouble from sagging or distortion. The concrete was mixed quite wet and thoroughly spaded next to the forms, so that we got a very smooth surface on the inside.

The work was performed under more than the usual difficulties, owing to the large amount of teaming that had to be maintained, poor banks requiring sheeting the whole distance, the presence in the trench for its entire length of a 12-in. gas main, and part of the way of an 8-in. main also.

The railroad is to be carried over Deane, Sawyer, Coggeshall, Cedar Grove, Weld and Logan streets by steel plate girder bridges, carrying three tracks, and over Wamsutta Street and Acushnet Avenue by the same type of bridge carrying four tracks. The girders of these bridges are carried upon steel columns set in the sidewalk just inside the curb line and not upon the abutments, with the exception of the bridge over Acushnet Avenue. Only the track stringers rest upon the abutments. The columns are set on concrete piers, whose foundations are 7 ft. square for all except the Acushnet Avenue bridge, where they are 8 ft. square. The tops of the piers are at the grade of the sidewalk. As already stated, these bridges have open floor systems, but the

ties are to be covered with 2 in. plank to prevent ashes, oil, etc., from dropping on the street below. As an additional protection to pedestrians, a canopy is to be built over the sidewalks the full length of the bridge.

The bridges represent a new departure in design and one that can hardly be commended as pleasing to the eye. The city, however, had no voice in the selection of the design as the decree says they "shall be proportioned and constructed in accordance with the General Specifications for Railroad Bridges of the New York, New Haven & Hartford Railroad Company."

By the terms of the decree the freight tracks at grade across Wamsutta Street are to be discontinued. This was supposed to do away with the Pearl Street yard and freight houses; so it was ordered that the small yard south of the passenger depot be enlarged and regraded, also that there should be built an outward freight house of brick, 360 ft. long by 30 ft. wide, and an inward freight house of brick, 360 ft. long by 50 ft. wide, together with platforms, tracks and driveways paved with granite blocks. The office building is on the end of the inward house. On the car side, these houses are practically a continuous line of sliding doors, so that there will be no difficulty about having the car doors opposite a door in the building.

The street built by the city and railroad as a continuation of Water Street on the west side of the freight yard has a driveway that is 32 ft. wide, paved with granite blocks on a concrete base. There is an 8-ft. sidewalk on the west side. The railroad driveway adjoining it on the east is about 45 ft. wide, thus making a continuous paved surface nearly 80 ft. wide, a fine and much needed improvement for the teamsters.

The car entrance to this yard is at Hillman Street; but trains must pull down across Hillman Street to the New Bedford and Fairhaven bridge and then be backed up into the yard to unload or load, to again be pulled out and backed up into the make-up and storage yard east of the main line and north of Maxfield Street. This latter yard was made by filling a portion of the water front.

The total area of the new freight yard, including driveways, is 239 000 sq. ft. The available length of trackage is 2 880 linear feet for houses and platforms and 2 385 linear feet for bulk freight.

The area of the make-up and storage yard is 447 000 sq. ft. and the total length of trackage, including ladder tracks, as laid out by the plans of the decree, is about 24 000 ft. Considerable

additions, however, have been made to this yard by the company on its own account. They have also abandoned the old round-house, turntable and coaling station south of Logan Street and built a new 6-stall round-house at the northeast corner of the new storage yard, also a new turntable, with concrete walls and bottom, capable of handling the heaviest engines on the line. This table never should settle, as it is built on a ledge of granite which formerly outcropped about 20 ft. above the present level of the tracks.

A short distance south of the turnable is the coal pocket and ash pit. The coal pocket has a capacity of 100 tons and is filled by a bucket elevator operated by an electric motor which takes the coal from a pit below the track where it is dumped from cars on a trestle to the east of the pocket. The ash pit is built of concrete with the standard fittings of this company. As this is made ground, the foundations for pocket and pit had to be built on piles.

Still further south is a new 50 000 gallon water tank, also built on a concrete and pile foundation. At present this tank is kept filled with city water, but later it is the intention of the company to relay its pipe from wells near the track south of the Acushnet Station.

Deane Street, Purchase Street and Sawyer Street, within the limits of changes in grade of same, have been macadamized. Weld Street, Acushnet Avenue and Wamsutta Street are paved with granite blocks on a concrete base. Logan Street is paved with granite blocks on a sand base.

The entire cost of eliminating these crossings was estimated in April, 1906, at $998 700. Of this amount, $823 700 was for railroad construction and engineering; $75 000 for street work, and $100 000 for land damages. This last item may be low, but the construction will come within the estimate. The railroad, however, has already spent a considerable sum and will spend more, outside the decree requirements, securing necessary additional facilities.

The engineer in general charge of this work is Mr. B. T. Wheeler. The engineer in charge on the work was Mr. J. W. Capron, to August, 1907, and since that time Mr. P. S. Perkins, all of the New York, New Haven & Hartford Railroad. The contractor is Mr. J. K. Ryan, of New York, whose representative on the work was Mr. J. F. Keon.

All work within the streets, outside of grading, has been done by the city under the general direction of the city engineer.

[Note. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by September 15, 1908, for publication in a subsequent number of the Journal.]

SOME CAUSES WHICH TEND TOWARD THE FRACTURE OF STEEL RAILS.

By James E. Howard, Civil Engineer.

[Read before the Boston Society of Civil Engineers, May 20, 1908.]

Steel rails, in service, are required to sustain direct loads of compression as well as bending stresses received from the wheels upon the running surfaces of the heads. Adequate strength may be provided for these stresses by suitable cross-section dimensions and disposition of the metal, in the same way they would be met in other engineering examples, but there are limitations to the intensity of the stresses which may be applied to the area of contact between the wheels and the rail. The latter part of the problem is peculiar to rails.

In reviewing the causes of fracture it is convenient to consider the subject under two headings: (1) Causes which depend upon or are chiefly influenced by the conditions of service, that is, those which the users of the rails are responsible for; (2) those traceable to the values of the physical properties, or the structural state of the steel in its relation to service requirements. The rail-makers have to do with the second group of conditions.

Under the first group of conditions, the effect of wheel pressures will be referred to. Fig. 1 shows the end view of a rail fractured in the testing machine. This represents a rail which had been in service and showed on the running surface of the head evidence of the flow of the metal caused by wheel pressures. In the fracture of this rail the initial point was at the inner edge of the running surface of the head, the center of radiation marking the place where rupture began.

The flow of the metal of the head, apparent to the eye, witnessed very generally in portions of the track, may be taken as evidence of exhausted ductility of the metal. The ability of the steel to elongate, as found in the primitive state of the rail before going into service, is lost by reason of its development, and the rail at first tough and capable of being bent is now brittle and will bend only to a limited extent before rupture.

The brittleness is due to the flow of the metal at and immediately below the running surface of the head. The structural continuity has not been destroyed, as may be shown upon anneal-

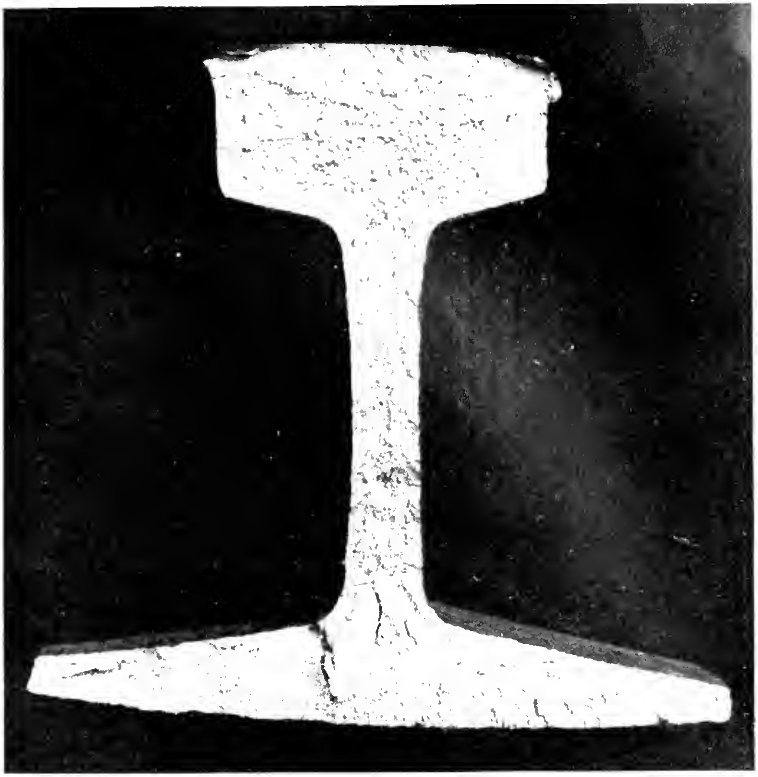
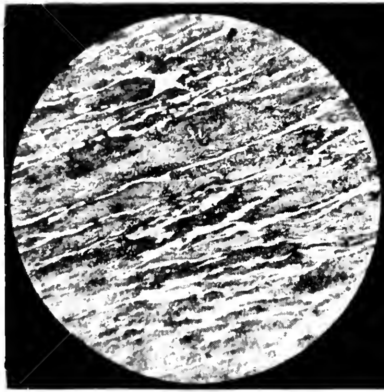
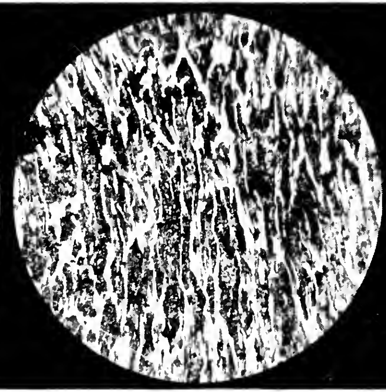


FIG. 1. End View of a Rail Fractured in the Testing Machine, showing Flow of Metal at Running Surface of Head due to Wheel Pressures.

FIG. 7. Difference in Bending Qualities shown by Rail after having been in service according to the Direction of Loading.





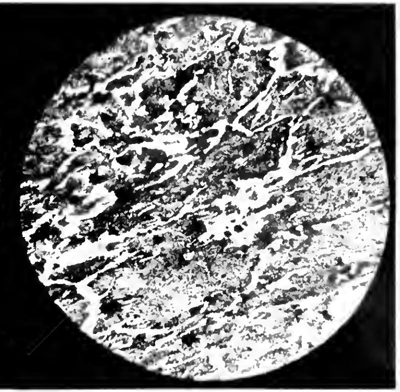


FIG. 3. Distorted Microstructure just below Running Surface of Head of Rail shown in Fig. 1.

FIG. 4. Distorted Microstructure of Fin at Edge of Rail shown in Fig. 1.

FIG. 5. Microstructure at Junction of Distorted and Unaffected Metal of Rail shown in Fig. 1.

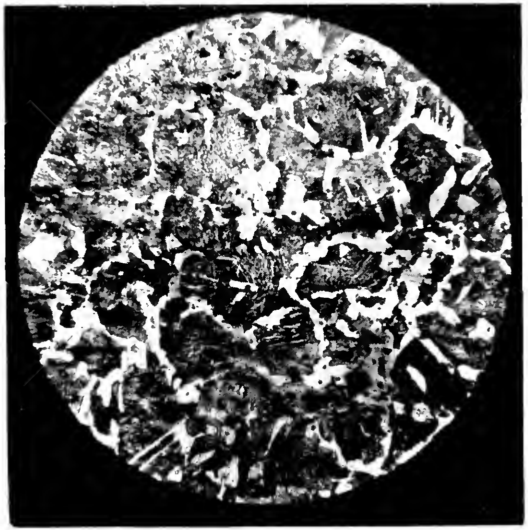


FIG. 2. Normal Microstructure of Metal in Head of Rail shown in Fig. 1.

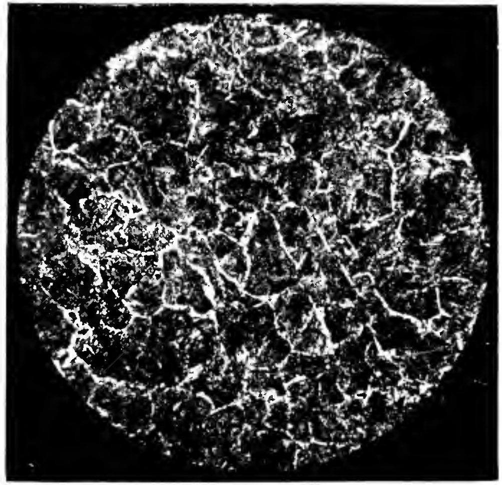


FIG. 6. General Microstructure of Head of Rail shown in Fig. 1, after Annealing. The same structure now pertains to the parts which had been affected by wheel pressures as to other portions of the head.

ing the metal, which effects a restoration in its ability to elongate. A rail from service will not bend well with the head on the tension side, since the surface metal has been subjected to cold flow in advance of its being worn away by abrasion.

Removing the surface metal, in the planer, restores the bending qualities of the rail, but in this case it is necessary to plane away the metal from the sides as well as from the top of the head, that is, as far down as the cold flow has taken place.

The distorted structure of the metal affected by cold flow is readily shown by means of the microscope. Figs. 2 to 6 inclusive are photomicrographs of different parts of the rail shown in Fig. 1, the magnification being about 84 and 110 diameters. Fig. 2 represents the normal structure of the metal in the head of the rail. Fig. 3 shows the distorted, flattened shape of the grains just below the running surface at the middle of the width of the head. The direction of flow was obliquely downward, which changed its course as the edge of the head was reached. At the edge, where a fin was formed, the longer axes of the grains are found in a position nearly vertical, as shown by Fig. 4.

The metal on the border between the affected and unaffected zones is shown by Fig. 5, the depth ranging from three to five hundredths of an inch below the running surface.

The sample from which these photomicrographs were taken was subsequently heated to a bright yellow color, which annealing heat effected a restoration in the grain of the steel, so far as uniformity of structure went. Fig. 6 shows the resulting microstructure, which resembles the normal structure in the primitive state, but somewhat finer in size.

The difference in the bending qualities of the same rail according to the head being on the tension or compression side is shown by Fig. 7. The upper piece of rail in the figure was bent with the head in compression, while the lower one of the cut had the head on the tension side of the bend.

Rails of this series of tests have ruptured with a deflection of only 3 to 5 degrees when the head was in tension, but remained unruptured when bent through an angle of 20 degrees or more with the base in tension. After annealing these old rails, of exhausted toughness, the bending qualities were restored, after which the rail could be bent in either direction through about the same number of degrees without fracture.

Fig. 8 is a side view of a rail broken in the testing machine, one in which lines of scale were detached from the surface of the web. The magnetic oxide is detached from the metal when

stresses reach or exceed the elastic limit of the steel. Places of overstrain in steel rails may be located by reason of the disturbance of the scale, and this takes place when rails are gagged in the process of cold straightening. While overstraining by gagging brings about a series of phenomena which tend toward final rupture, still it has not been the privilege of the speaker to examine any fractures in rails which seemed to owe their origin to this cause.

Fig. 9 represents another rail fracture made in the testing machine. The rail was tested with the base on the tension side. The cut is introduced to show the effect, in locating rupture, of a slight indentation made on the upper edge of the flange, the fracture of this sample having started at an indentation on the right flange of the base, the cut printing too deep to clearly show the place in this illustration.

It is desired to emphasize the fact that steel surfaces generally afford the means of judging where a line of fracture has its origin. In the case of granular fractures the center of radiation marks the starting point, the recognition of which is an aid toward ascertaining the cause which contributed toward rupture.

The slipping of the driving wheel of the locomotive when starting a train may cause roughness of the metal of the rail accompanied by intense heating of the immediate surface metal of the head. The appearance of the running surface of a rail head which has been subjected to this treatment is shown by Fig. 10. Necessarily tires and brake shoes are exposed to similar treatment, but rails only will now be referred to. In addition to the loss in ductility of the steel by reason of its flow under the wheel pressures, the metal at the running surface is hardened through this action of the wheel. Showers of sparks attend instances of this kind, from which the high temperature acquired by the particles of the steel may be judged of. There follows also a sudden reduction in temperature through conductivity of the cold metal below, which has an effect similar to quenching steel from high temperatures in water or other quenching liquids, and there results a surface hardening of the metal.

During this period of hardening the surface metal is placed in a state of intense tension, relief from which is experienced by the development of cracks in the steel. These cracks are a menace to the integrity of other parts of the rail, and may extend and result in complete fracture. Fig. 11 shows, at the darkened corners of the running surface, thermal cracks, which had begun to extend into the head, the result of this hardening proc-

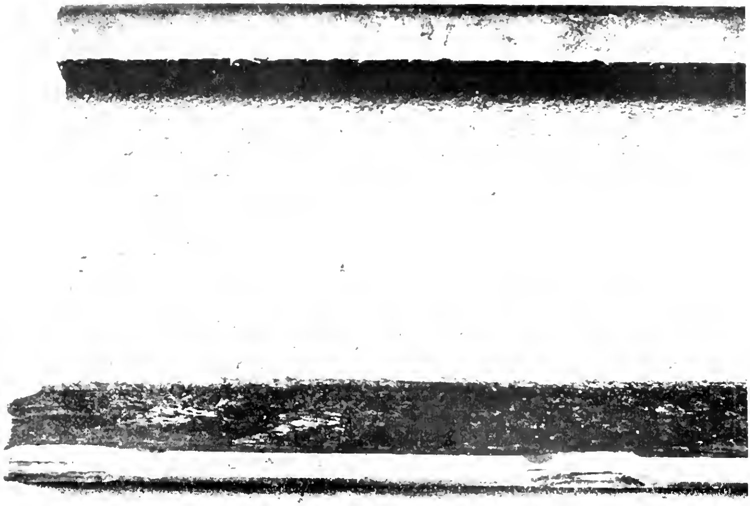


FIG. 8. Side View of Rail, Broken in the Testing Machine, showing how Scale was Detached from Surface of Web.

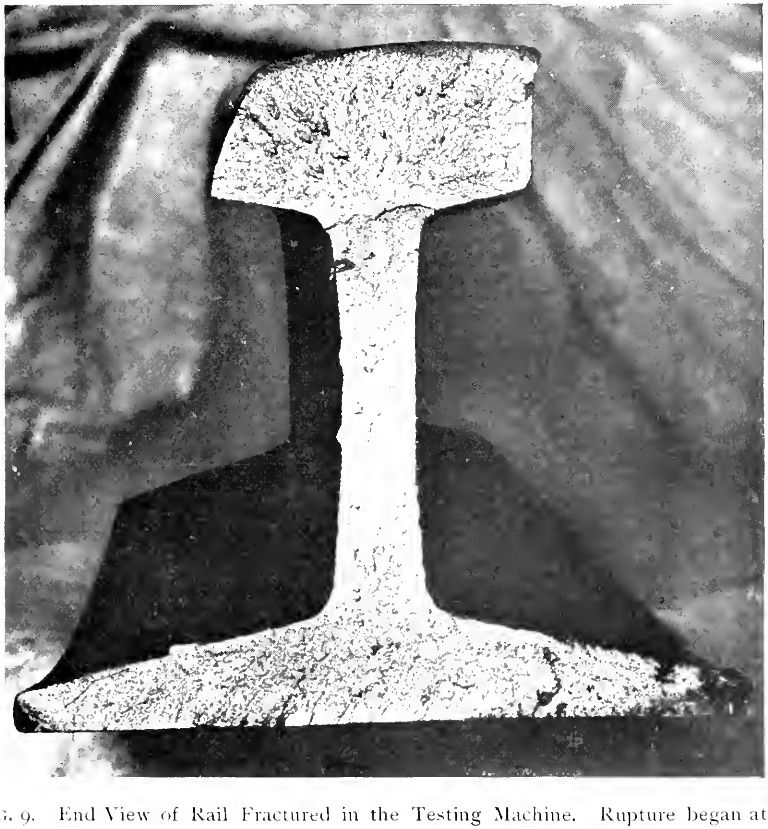


FIG. 9. End View of Rail Fractured in the Testing Machine. Rupture began at an indentation on upper edge of base, right-hand side.

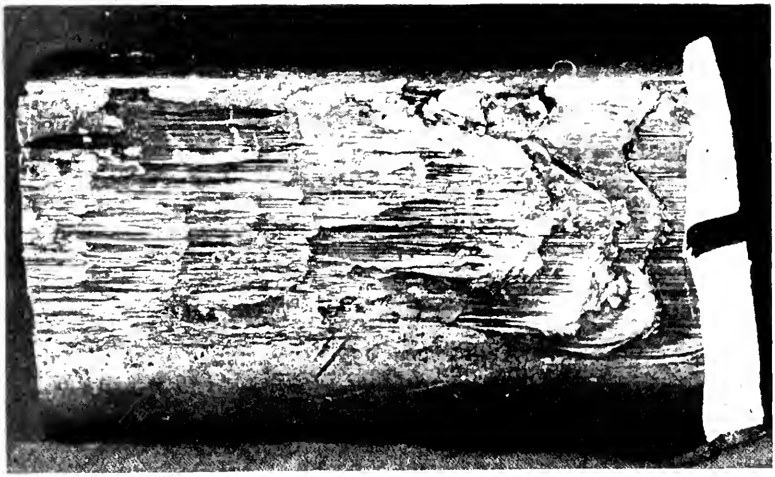


Fig. 10. Running Surface of Head of Rail, Roughened by Driving Wheels of Locomotive. Surface Hardened and Thermal Cracks Started.

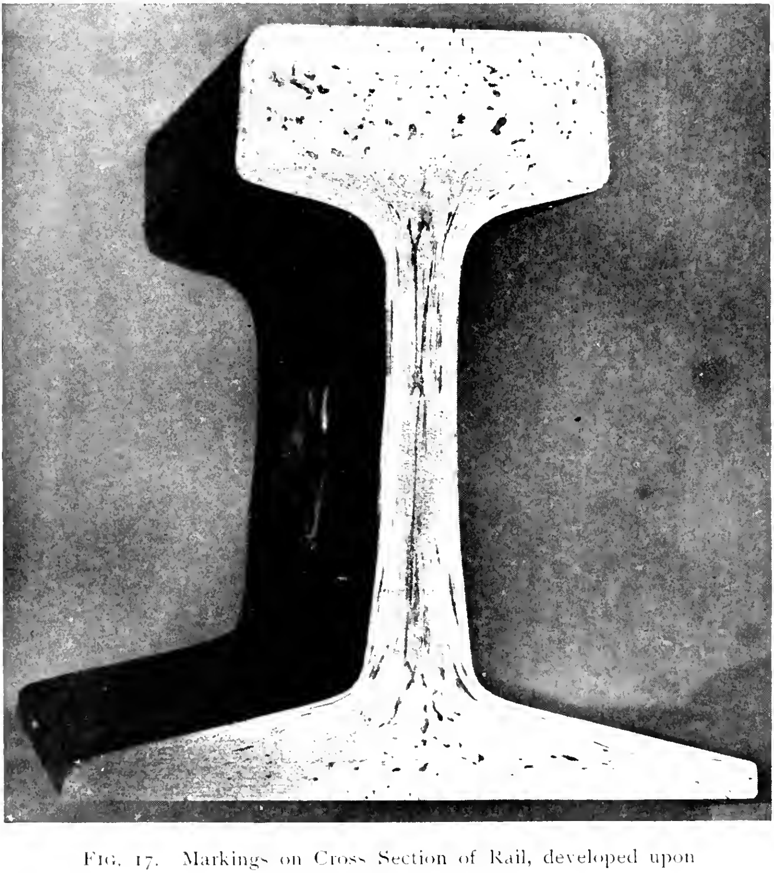


Fig. 17. Markings on Cross Section of Rail, developed upon Polishing and Etching.

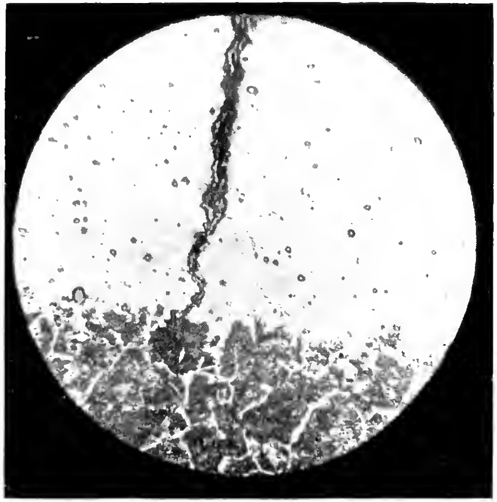


Fig. 15.

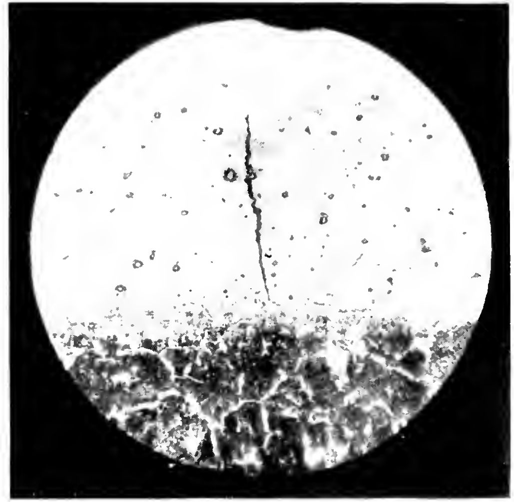


Fig. 16.

Thermal Cracks in Head of Rail shown in Fig. 10. Magnification 110 Diameters. Cross Section of Rail.

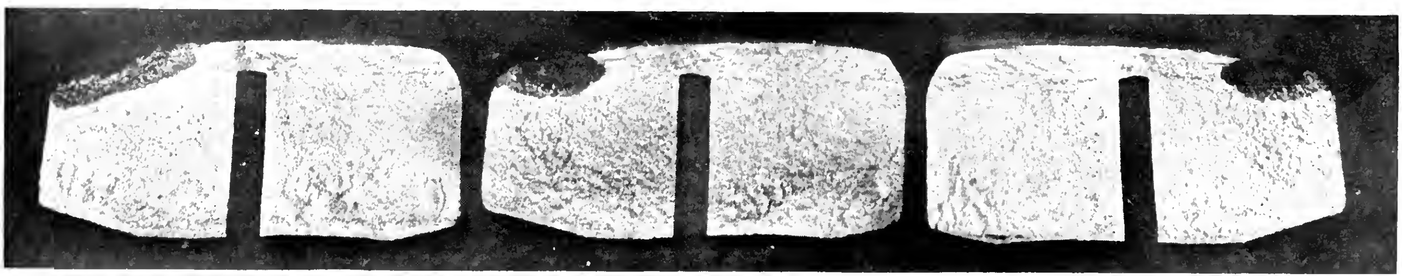


Fig. 11. Cracks Started in Head of Rail shown in Fig. 10, caused by Action of Wheels of Locomotive. Dark corners indicate the cracks which were developed.

FIG. 12. Upper End.

FIG. 13. Middle Portion.

FIG. 14. Lower End.

Thermal Crack in Head of Rail shown in Fig. 10. Magnification 110$\frac{3}{2}$ Diameters.
Longitudinal Section of Rail.

ess. Fractures thus begun may progressively extend deeper and deeper until there is a serious weakening of the rail.

A microscopic examination was made of the thermal cracks which had formed in the head of this rail and are illustrated in Figs. 12 to 16 inclusive. The first three of these figures show parts of the same crack, taken at different depths, successively, the magnification being 110 diameters. In Fig. 12 the hardened metal, immediately below the running surface, appears white in the cut, this portion not being acted upon by the etching bath, a 4 per cent. solution of picric acid. This crack is viewed on a longitudinal section of the rail head. The upper portion has a curved direction corresponding to the flow which the surface metal experienced before hardening took place. The central part of the depth of the crack is shown in Fig. 13, and the lower part in Fig. 14.

Figs. 15 and 16 show thermal cracks as found on a transverse section of the head of this rail. The cracks are formed in direction nearly normal to the running surface, the flow of the metal under the wheel pressures not causing a curved shape such as witnessed in the cracks which were viewed on the longitudinal section of the head. One of these two cracks is seen to have separated the hardened portion of the head and reached into the unhardened metal below, while the other crack is an interior one lying wholly within the zone of hardened metal.

With the presentation of these illustrations the causes of steel rail fractures resulting from service conditions will be left and metallurgical features under the second heading taken up.

When a rail is cut apart and its cross-section polished and etched, certain markings usually appear, the general character of which are similar to those shown by Fig. 17. They not infrequently appear to the eye before etching, a suitable machine-tool cut having been taken across the rail section.

A 10 per cent. solution of iodine was used in the etching of the sample represented in the present figure. These familiar markings indicate a lack of uniformity of some kind in the steel.

Markings, which appear as dots or lines on the cross-section of the rail, are found to be streaks, some of which are light colored and others dark colored, when a longitudinal section of the rail is examined.

Fig. 18 shows one pronounced streak which can be followed over the edge and seen on both the top and the end surfaces of the rail. Since the dots and lines on the cross-section are found at different places in the rail, their connection with longitudinal

streaks having been established, it follows that streaks will be found at different depths from the surfaces when the metal is examined by planing off the heads or bases in steps at different depths. Fig. 19 shows the head of a rail planed off at two steps, an inclined section connecting them.

Longitudinal lines on the bases are similar in appearance to those which are found in the heads. Fig. 20 shows the base of a modern rail of domestic manufacture, while Fig. 21 shows streaks in the base of an early English rail.

It may properly be inferred that streaked rails are not confined to those of recent manufacture, although it should not be assumed that all kinds of streaks are equally detrimental to the integrity of the rail.

With the view of determining some of the characteristics of the metal at the dark colored dots and lines, a thin cross section of a rail was planed off, as shown by Fig. 22. Upon bending the several parts of this thin section, which was first cut apart detaching the web from the head and base, it was found that the metal ruptured more readily along the line of a streak or at the dark dots than in other portions of the steel.

The effect of these streaks in causing brittleness is a matter upon which there can be no doubt, and since the so-called "moon-shaped" fractures in the bases of rails have their origins in longitudinal paths, the primary cause of such breaks is attributed to the presence in the steel of the longitudinal streaks just described.

Fig. 23 shows a fracture in the base of a rail, one which was formed in the testing machine, a typical "moon-shaped" or crescent break. This fracture was made along the line of a streak, and in continuation of one which occurred in the rail when in the track.

Extreme brittleness generally characterizes these breaks; the metal along the streak presents a striated appearance on the fractured surface, and preceding rupture there is hardly any display of permanent set in the metal. Photomicrographs, Figs. 24, 25 and 26, show the behavior at a streak when moderate bending stresses are applied, bringing the metal into tension in that part of the rail. The magnification of these figures is 150 diameters.

Fig. 24 shows the primitive state at a place on the base of a rail, the continuity of the material across this streak being unimpaired when first examined. Upon straining the sample containing this streak a fissure was developed, which may be seen in Fig. 25 as an irregular dark line within the borders of the streak.

FIG. 18. Markings on Cross Section of Rail, developed upon Polishing and Etching, showing Connection between End Markings and Longitudinal Streaks.

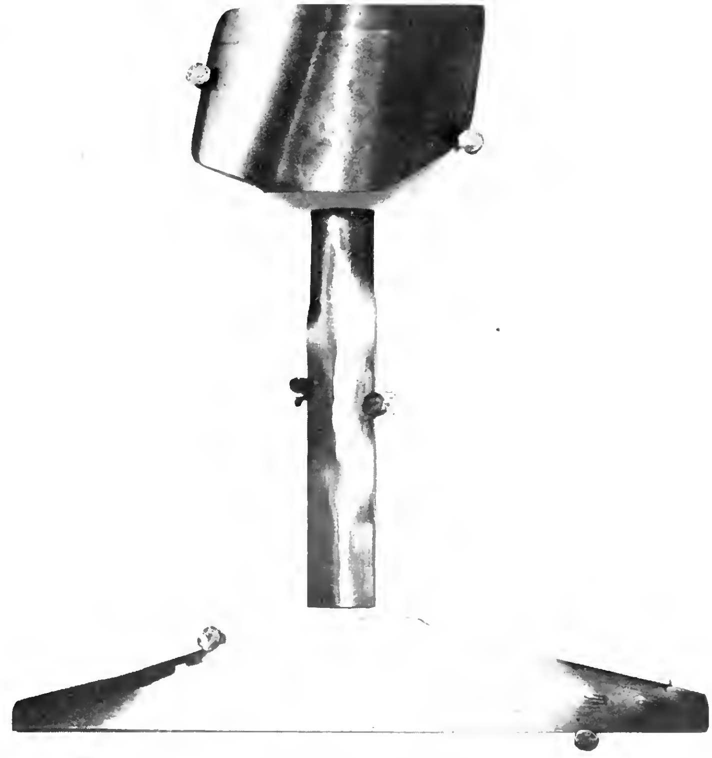


FIG. 22. Bending Tests made upon a Thin Section of Rail, showing Fractures on Line of Streaks or at Dark Colored Dots developed by Etching.

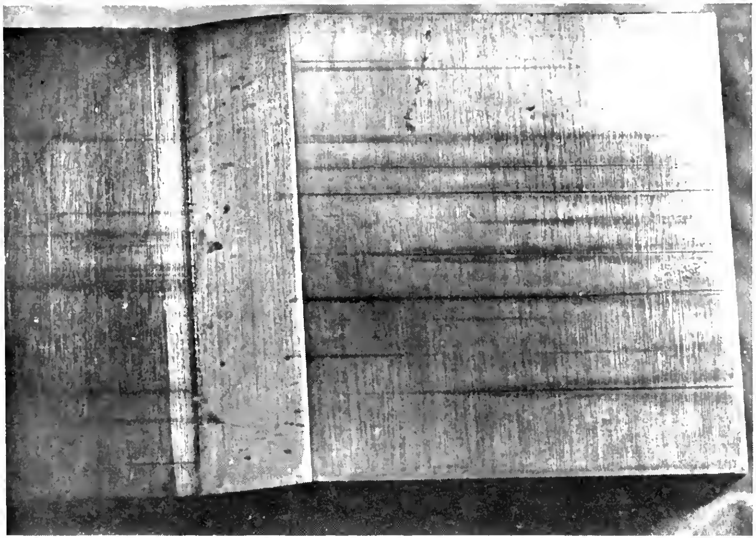


FIG. 19. Longitudinal Streaks on Head of Rail, at Different Depths.

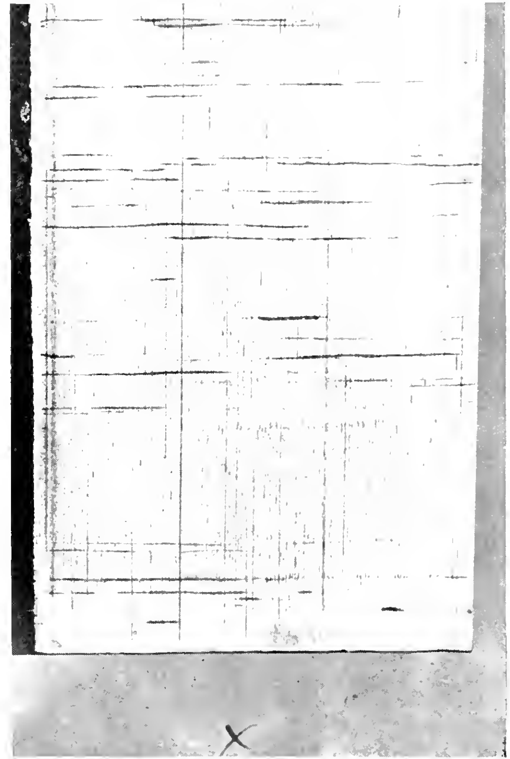


FIG. 20. Longitudinal Streaks on Base of Rail of Domestic Manufacture.

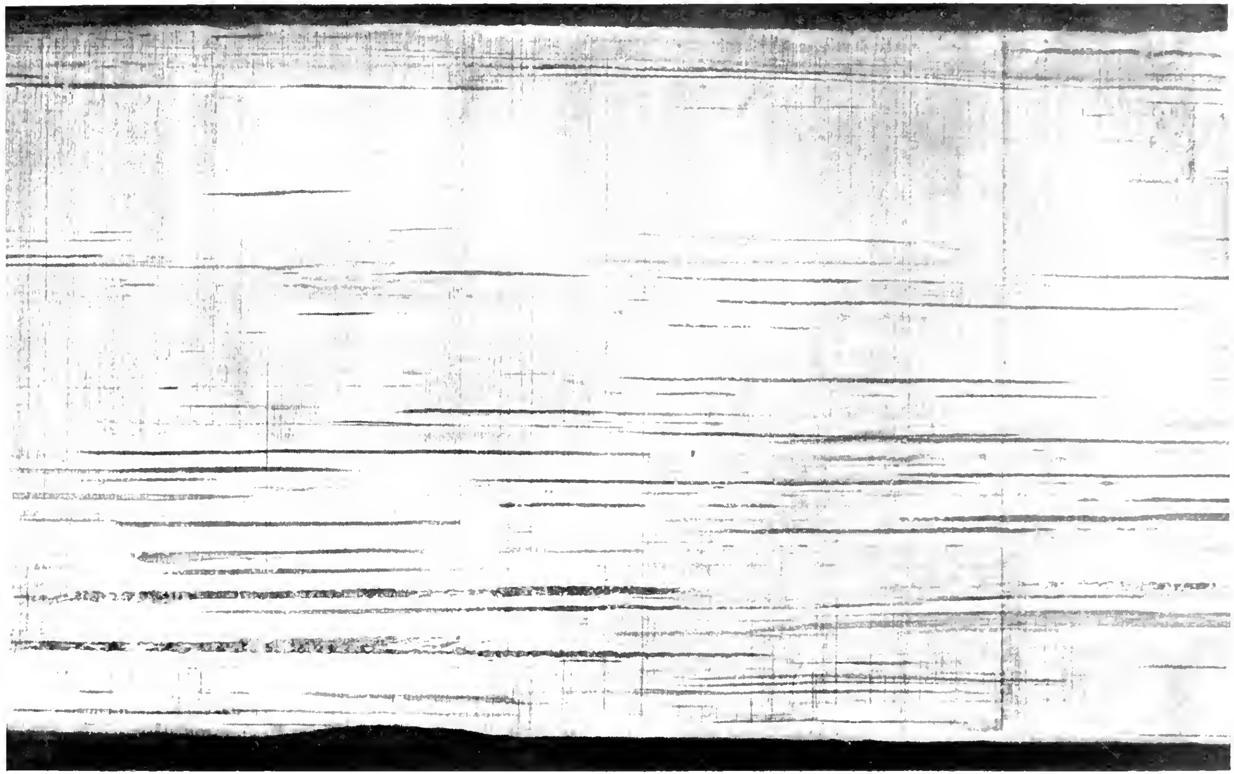


FIG. 21. Longitudinal Streaks on Base of Rail of Early English Manufacture.

Fig. 23. "Moon-Shaped" Fracture in Base of Rail. Fracture made in the testing machine on the line of a streak, in continuation of one which occurred in the track.

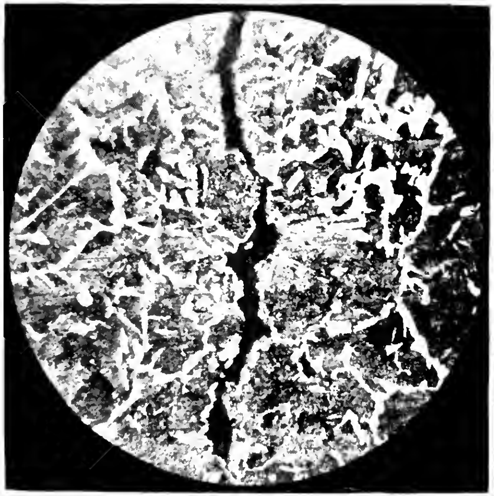


Fig. 24. Primitive State, before Straining.

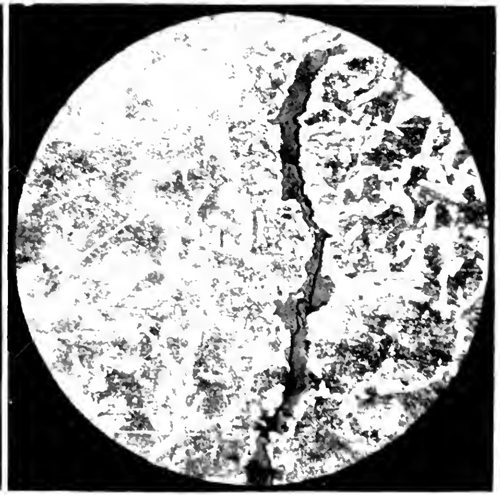


Fig. 25. Appearance after having been Slightly Strained, a Fissure Opened along the Line of the Streak.

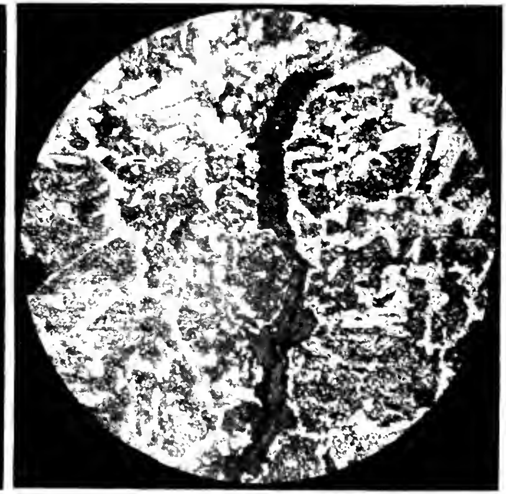


Fig. 26. Appearance after Further Straining, Increasing the Width of Fissure shown in Fig. 25.

Microstructure in Vicinity of Streak in Base of Rail. Magnification 150 Diameters.

The straining force was so slight as to hardly cause an appreciable permanent set in the base of the rail.

The same sample was bent again, a little further than on the former occasion, resulting in an enlargement of the fissure, as shown by Fig. 26. Dr. Henry Fay, in collaboration with the speaker, recognizes the material in this streak as manganese sulphide, and furthermore that the thermal cracks in the running surface of the rail previously referred to also passed through streaks of manganese sulphide.

From this it would seem that certain of the streaks are fissures in which there is lack of continuity of the steel, the narrow space between being occupied by a substance having little adhesion to the walls thereof.

DISCUSSION.

Mr. J. Parker Snow (*by letter*). — Rails fail in service in a variety of ways. Broken rails can generally be grouped into four classes:

1. Square break.
2. Crescent break and its derivatives.
3. Split head.
4. Split web.

Failed rails that do not actually break also show four groups:

A. Crushed head.
B. Flow of metal.
C. Shelly corner.
D. Worn head.

1. A break coming under the class of square breaks may be square or angular or curved so far as the relation of its surface to the axis of the rail goes. The line of the fracture across the base, however, is generally straight whether square across or at an angle with the line of the rail. Breaks under the drop test and in a testing machine, when loaded as a beam, are generally of this class. Anything that renders steel brittle, like coarse grain, high phosphorus, concentrated manganese, segregated carbon, the presence of oxides, silicates or sulphides, or the crushing of the metal by excessive wheel loads, skidded wheels or slipping drivers, will cause rails to break in this way, as well as loads that overcome the ultimate strength of the metal. In ordinary service at the present day these breaks are few.

2. The great majority of the broken rails that have occurred in this vicinity in recent years are of the crescent type. These

fractures start from a longitudinal flaw of some sort near the center of the base and run with the flaw, sometimes a fraction of an inch; sometimes as much as six feet and then break out to the edge of the flange in a crescent shaped curve. Sometimes one side only of the base breaks out and rails have been known to do service for years in this condition. Generally, however, a rail weakened in this manner breaks through the other flange, the web and the head, immediately. The break through the web and head are exactly like a square break. The fracture across the base is not a straight line as in the first class, but such as will leave a cusp point on one part of the base and a corresponding re-entrant angle on the other, oftentimes accompanied by a split along the prolongation of the seam that caused the fracture. It is generally possible to distinguish the flaw, at which the fracture started, as a smooth seam face, sometimes so open that it is strongly corroded, sometimes close and showing a bluish surface like mill scale, but sometimes granulated as though it had been weakly stuck together like a soldered joint. Sometimes these seams will be exactly vertical and may at the ends pinch out by passing upwards into the metal. Sometimes they are inclined to the vertical with their sides fluted and in this case they do not pass up into the metal at their ends. I may say that in all the cases of crescent breaks that I have examined, and that is a good many, it has always been possible to discern the manifest flaw from which the fracture started. A better name for this type of failure would be, perhaps, "split base," for the initial point of the break is a longitudinal split in the base.

3. Split heads have caused a great deal of trouble on some roads. One side of the head splits off nearly in the plane of the side of the web. The piece split off may be but a few inches long or it may be as much as ten feet long. Pipes in the ingots may cause some of these splits, but indications of seams in the heads are sometimes present, similar to those above described in the base. Split heads caused by these minute seams are probably brought about by what are known as progressive fractures. That is, the little flaw works downward under the blows and vibrations from the wheel loads and finally gets to the underside of the head and the piece drops off.

4. Split webs occur in considerable numbers in some regions. The web splits horizontally at the end of the rail, generally through the bolt holes. It is analogous to failure from longitudinal shear and is probably an indication of excessive internal strain due to unequal shrinkage of head and base in cooling.

A. Many rails fail by the so-called crushing of the head. On many lines carrying heavy equipment, this class of failure covers the majority of defective rails at the present time. In this type the head flattens and broadens out, the sides of the head generally sag down, decreasing the fishing angle, and if continued in use the head finally splits and slumps down.

B. When the metal on top of the head rolls out to the sides and forms an overhanging lip without any indication of a breaking up of the structure of the metal, it is called " flow of metal." Steel that shows this phenomenon is certainly ductile, but is not rigid enough to carry the wheel loads imposed.

C. Shelly corners produce a condition somewhat similar to flow of metal, but in this case there is certain evidence of unsound structure. The corner of the rail slumps down and frequently peels off. Rails with this defect are very common. They often show low spots on one or both corners, one to two inches long, scattered along the length of the rail, a few inches to several feet apart. Each and every one of these spots has an open seam under it. They appear to be due to seams like those producing split heads and crescent flange breaks.

D. Excessive and rapid wear of the gage side of the head by the wheel flange comes under the class of worn head. If unduly rapid and due to the quality of the steel, we can suspect segregation or unsoundness, due to the presence of undesirable oxides, silicates or sulphide, or coarse grain due to improper heat treatment.

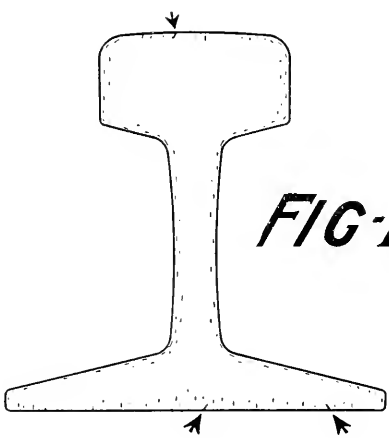


FIG-1

The author of the paper has shown us in a very instructive way some of the manifestations of unsoundness in our rail steel. To show how two kinds of these flaws appear to me in the actual rail, I submit Fig. 1. The short marks on the section are intended to represent actual fissures in the steel. Narrow lines represent the minute fissures accompanying light streaks which I have called in previous discussions " gas seams." The three broader lines indicated by arrowheads represent what I call

"rolling flaws." It is almost impossible to see these flaws in the cross-section of a rail without very high magnification, but they show very plainly when the metal is cut longitudinally at right angles to their planes. Considering, first, the gas seams: it will be noted that the lines are vertical in the lower portion of the base and top of head. At other points they are shown more or less parallel to the surface. The positions are conjectural to some extent, as I have not traced them entirely around the contour of the rail; but at the junction of the web and base they certainly follow the surface as indicated and are vertical in various other parts. They seem to lie parallel to the pressure of the rolls. But few of them reach the actual surface and they do not extend into the metal very deep, except sporadically. This distribution seems to follow that of the white streaks in the steel examined by Mr. Howard.

I call these flaws, gas seams, because they appear to follow the location and characteristics of gas bubbles that are so generally found in steel ingots. A zone of bubbles is almost invariably formed around the sides and across the bottom of steel ingots from 1½ to 6 in. from the outside. These are closed by the rolling, but cannot thoroughly weld. If parallel to the surface or deeply seated, say ½ in. from the outside of the rail, they do not seem to work much harm.

The subject of gas bubbles or blow holes in steel ingots was treated quite exhaustively by Mr. E. von Maltitz, metallurgical engineer of the Illinois Steel Company, in a paper before the Institute of Mining Engineers in July, 1907, wherein he shows that where recarbonizing is done in the ladle and insufficient time allowed for the complete reduction of the iron oxide in the bath, an excessive number of gas holes may be formed. Moreover, the manganese protoxide, silicates and sulphides formed by this reduction may not have time to separate into the slag before the steel reaches the mold. In this case small nodules of these manganese salts may occur as inclosures in the metal, rendering it brittle. Such inclusions may be expected, then, in connection with gas holes, as was shown by the microphotographs on the screen.

The three flaws of Fig. 1 (marked by arrowheads) will be seen to be wholly at the surface of the metal and to be few in number. They are frequently inclined to the surface and are more or less crooked when viewed in plan, whereas the gas seams are remarkably straight and true. When opened up, their surfaces are always smooth, precluding the possibility of their ever

having been stuck together. Sometimes they are so open that they can be traced on the base before the rail is laid. In this case when broken their sides are well rusted. Sometimes they are so close that they do not corrode and when opened their sides are bluish like mill scale. Their line is generally somewhat crooked and their sides are often fluted longitudinally. I call them rolling flaws, because I believe they are the product of surface defects in the ingot or bloom. It is well known that shrinkage cracks or checks occur in the skin of ingots and that tears occur in the surface of blooms during the early passes through the rolls. Formerly these checks and flaws were carefully chipped out before rolling was proceeded with, but for a decade or more this precaution has been omitted at most mills because it was found that such wounds would close up in the rolling process and lead to but very few rejections.

I have seen at Mr. Howard's laboratory a slice from an ingot with a shrinkage crack more than 6 in. long and $\frac{3}{4}$ in. deep. What would become of this when rolled out into a rail? It would not weld. It is a ragged, irregular opening and would roll into a more or less crooked seam. The metal might be crowded sideways, so that its plane would become inclined and perhaps curved and the roughness of the original would result in flutings and striae such as these defects show. It seems to me the genesis is complete.

A third element of unsoundness in rails, not shown in Fig. 1, is exhibited by the dark streaks found in the deeper cuts in the metal. These do not show on the polished surface unless etched. They show finely in cross-section and seem to be closely allied to segregation. The inclusions of manganese salts, mentioned above, may be a part of the galaxy of dark streaks, leading to the familiar figure so often illustrated in rail sections. Segregation is inevitable in the solidification of steel, and if normal can be so disposed of as to cause but little trouble.

Can we now correlate our various types of failed rails with the three classes of defects that stand confessed in the steel of which they are made?

1. Square breaks can hardly be charged to any of these defective features. They are probably due to accidentally high carbon or phosphorus or to service conditions beyond the capacity of the rail. Steel loaded so as to cause a change in its structure, as shown on several of Mr. Howard's slides, renders rails peculiarly liable to square breaks. Such indications show the limit of wheel loads for carbon steels.

2. Crescent breaks, or more properly split bases, I believe to be due to longitudinal weakness in the rail as rolled. A rail is supposed to be supported by the tie uniformly across the width of its base. The load comes to the center of the base through the web. These forces produce a moment tending to split the base longitudinally. If the metal is sound, the strains set up are not great enough to produce fracture or even distortion; but if the base is full of incipient seams, fracture will naturally follow. The fiber strain, produced by the moment referred to, is greatest at the center of the base. We find most of the fractures starting from the center or just under the side of the web, and although the examinations described by Mr. Howard show us that there are seams across the whole width of the base and throughout the metal of the base, it is the seams near the center that determine the fracture.

My examination of these breaks leads me to think that rolling flaws lead to far more failures than gas seams or streaks of included salts of manganese. My reason for this conclusion is that invariably a smooth seam-face, characteristic of rolling flaws, is discernible at the initial point on the corner of the break of the crescent broken out.

If rolling flaws and surface gas seams are not the predisposing features that actually lead to these breaks they are certainly competent to do so, and their elimination or proper control is greatly to be desired.

3. Split heads may be, and I believe are, caused by the same class of flaws as base breaks. The actions of the wheel load and web are the same as described above, except that the lever arm producing the moment is much less. How can the head be expected to hold together when it contains open fissures such as Mr. Howard's investigation has revealed? Pipes and wide plates of included sulphides lead to some failures of this class without doubt, but the diagnosis given here and in the previous paragraph 3 appears to me more widely applicable.

4. Split webs are not attributable to any of the three classes of defects described above. They are probably due to a condition of internal strain that would be wholly removed by annealing if that was practicable.

As to the four groups of rails that fail without breaking:

Group A. Crushed heads can be traced directly to unsound metal. Mr. Robert Job, while chemist of the Philadelphia & Reading Railway, studied this matter thoroughly and discussed it many times. He showed that in every failure of this sort a

polished end section showed marked unsoundness. Excessive segregation and veins of manganese salts, shown on the screen as dark streaks, render the metal liable to rapid crushing. It is evident, too, that a wilderness of vertical flaws like the gas seams shown on our Fig. 1 will weaken the head greatly. In fact, Mr. Job says that unwelded seams near the surface of the head cause far more failure than segregation.

B. Flow of metal occurs, of course, when the rail is too soft; but improper heat treatment at the mill, such as will cause the grain to be coarse, is the usual cause of this defect. One reason for the magnificent service of early English steel rails is the fine, even texture of the metal. John Brown rails, although full of segregation streaks and of execrable chemistry, do not flow because the texture of the metal is fine.

C. Shelly corners can be traced directly to gas seams or veins of manganese salts, parallel to the surface at the corner of the rail. Sound rails do not give way at the corners, but metal containing these seams cannot stand the severe torsional shearing imposed by the wheels of heavy equipment at high speed.

D. Worn heads must be expected to a reasonable extent. It is only those that wear unduly fast that can be attributed to defective steel. Coarse structure due to hot finishing is certainly deleterious, but the three metallurgical defects that we have been discussing can hardly be charged with this type of deterioration.

Hence, of the eight types of broken and failed rails, we can claim four, viz., crescent breaks, split heads, crushed heads and shelly corners, as due to structural defects in the steel. It is probable that there never has been a perfectly sound rail rolled; and, what is more, it will probably be impossible to ever produce a rail from melt-made steel that will be wholly free from internal defects. With all the flaws that have been shown to be so common, it is likely that a thousand rails give satisfactory service to every one that fails. This means that these defects can be tolerated if kept within proper bounds. The studies so far made at Watertown Arsenal have shown us the nature of many of the defects. We hope that further study will show us the cause of these defects. Then it will be in order to study methods for obviating the causes.

In my opinion gas seams and rolling flaws are far more vicious in their effects than segregation or inclusions of manganese salts.

Mr. Job claims that if these defects are kept well within the

metal, say $\frac{1}{2}$ in. from the surface, they will do but little injury. Mr. von Maltitz shows in his paper, referred to above, how gas bubbles can be controlled and prevented from forming near the surface of the ingot; so that by proper manipulation of the melted steel it seems possible to eliminate gas seams from the list of dangerous defects. Rolling flaws, the most dangerous of all seams, are necessarily on the surface. They are due to cracks in the skin of the ingots or blooms, or to folds in the metal, while it is being rolled. Many cracks occur in the blooms due to heavy reduction. This certainly can be obviated; shrinkage checks in the ingots can be chipped out; and folds can be prevented by careful reductions in the rail train. The absence of crescent breaks in John Brown rails is due, no doubt, to the fact that careful rolling produced no rolling flaws. If rails could be rolled without these flaws forty years ago, they can be rolled so now.

If seams are present, but have their planes parallel to the surface, as occurs on the top side of a rail base and in plates and shapes of structural steel, but little trouble arises from them. If rails could be formed in a Gray mill, as appears possible, the plane of gas seams, at least, would be so disposed. The finishing pass of a blank so rolled could be made in a grooved roll.

Inclusions of manganese salts can be controlled, and mostly prevented, according to von Maltitz, by using care not to over-oxidize the bath and by giving time for these salts to rise into the slag before the charge is teemed into the molds. Dr. P. H. Dudley, of the New York Central, requires a definite interval of time between the additions of the spiegel and the teeming of the steel.

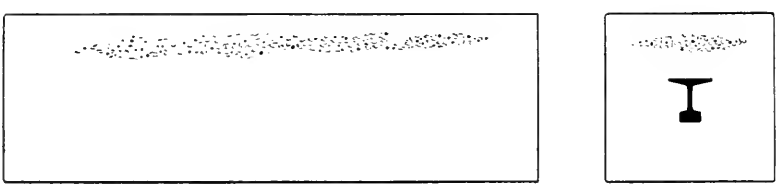


FIG-2

As to segregation, a considerable number of years ago it was the custom at some mills to throw the ingots on their side for charging into the soaking furnace. This caused the segregate to form along the top side of the ingot as indicated in Fig. 2. The mass was then handled in such a way that the base of the rail was

formed from the segregation side, as shown in the figure. This left the head practically free from segregated material. Ingots are now kept on end until they go into the blooming rolls. The segregate is consequently central in the mass and the sections that have been shown on the screen prove that the segregate is in both the head and the flange. If an ingot is rolled into a slab and sheared lengthwise into two billets, as indicated by Fig. 3, and the billets passed to the rail train, so that the base is formed from what was the central part of the ingot, the heads will be formed of metal practically free from segregate. The figure shows the relative position of the rails.

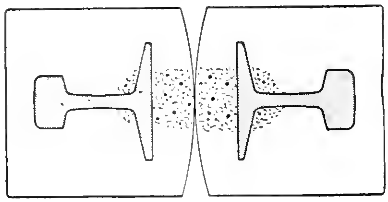


FIG. 3

There is very much in the metallurgy and manufacture of rails not touched upon in this paper. I have dealt only with common failures in rails and the manifest defects in the steel that render rails so liable to these failures. The suggested remedies are so obvious and so simple in application that the continued production of such defective rails as have been furnished during the present decade seems to me a disgrace to American industry.

Prof. Henry Fay. — Last summer and winter there was so much in the papers about the breakage of steel rails that it occurred to me there was probably something still to be learned in regard to the cause of such breakage. I determined, last winter, to make some investigation along that line, and since the 1st of January I have been engaged with one of my students on this subject, and personally I have been associated with Mr. Howard in some of his work and have reached some important conclusions.

I must differ, I think, from Mr. Snow as to his conclusions in regard to the importance of what he calls manganese salts. The reason why I can't agree with Mr. Snow, I want to tell you. The first piece of rail I examined was a small piece, broken out or knocked out by a hammer, which showed a check, the check being smooth and entirely different from the crack or fracture. The photograph clearly shows this. The metal was cut through about one-quarter of an inch away from this check, polished, and examined under the microscope. On the same line with the check was a long streak of manganese sulphide extended in the

direction of the rolling. Photograph No. 2 illustrates this appearance in a long, thin line. That evidently produced the check; but we hadn't sufficient evidence to say that it did. I then proceeded to examine a number of crescent breaks, and to my surprise found they were invariably associated with a very large amount of manganese sulphide.

I want to tell you something in regard to the character of manganese sulphide. Manganese sulphide melts at 1162° cent. Its specific gravity is 3.96 or about half that of steel. It is a glassy, hard, extremely brittle material. The steel from which the rail is made solidifies at about 1450° cent. and the manganese sulphide will not solidify until it reaches 1162°. Therefore, the manganese sulphide is in a fluid state some time after the steel solidifies. If the rolling of the rail starts, we will say, at a temperature above 1162°, this material will be rolled out in thin strips in the direction of rolling. It is plastic below the melting point and it is capable of being rolled out while in the plastic condition into long, thin strips. Manganese sulphide may not be the cause of all crescent breaks, but if we take into consideration in this connection the fact that you can predict where a break is going to occur, and say that a break will occur along the line of manganese sulphide, I think the evidence is almost conclusive.

Mr. Howard has shown one or two figures in which the crack followed through the manganese sulphide. That would not have been so remarkable if it had not been predicted beforehand that the break would occur through this area. This prediction I made, and the crack occurred as predicted. More recently I have shown in the work with Mr. Wint, at the Institute of Technology laboratory, that metal cut from crescent breaks when strained will start cracks every time through the manganese sulphide before a crack starts in any other part of the metal. In all cases examined the metal shows very little ductility, and I think that is good evidence that we have an extremely brittle material. I do not think the importance of the observation that cracks will begin in manganese sulphide areas can be overestimated, and I believe the remedy is simple.

The cause of the manganese sulphide being in the steel is comparatively simple. When the spiegel or ferro-manganese is added to the molten metal after the blow, the manganese combines with the sulphur and, given time enough, manganese sulphide, having a specific gravity less than that of steel, will rise to the surface. Give it more time and it will purify itself.

FIG. 1.

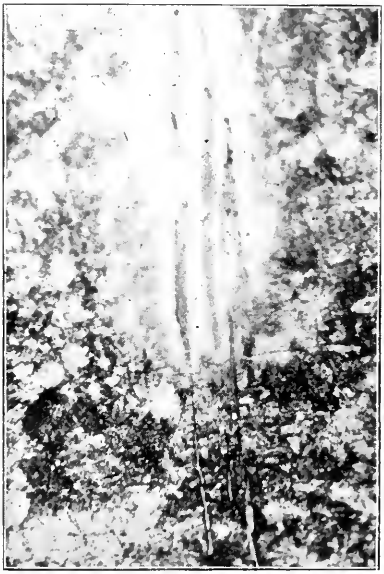
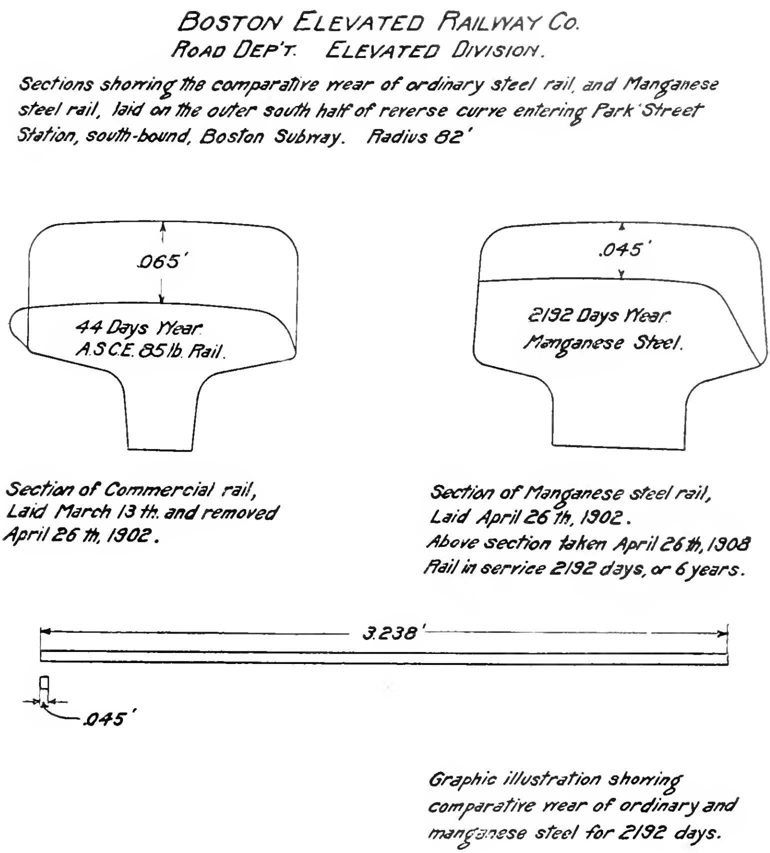


FIG. 2.

Mr. Parker. — We have heard much about phosphorus, and I understand that the Pennsylvania Road has given up the use of Bessemer steel because they found that phosphate ore is exhausted.

The President. — Can anybody explain what Mr. Parker wants to know about phosphorus?

Professor Fay. — I might say that the Pennsylvania Road has not ceased to use Bessemer steel, but in their new specifications they call for not more than 0.1 of 1 per cent. of phosphorus. In a Bessemer rail they allow, I think, 0.55 per cent. of carbon and not over 0.1 per cent. of phosphorus. In open-hearth material, where there is less phosphorus, more carbon is allowed.



Mr. George A. Kimball. — I have been very much interested while listening to these valuable papers, and the remarks which have followed have also been very instructive. The Bos-

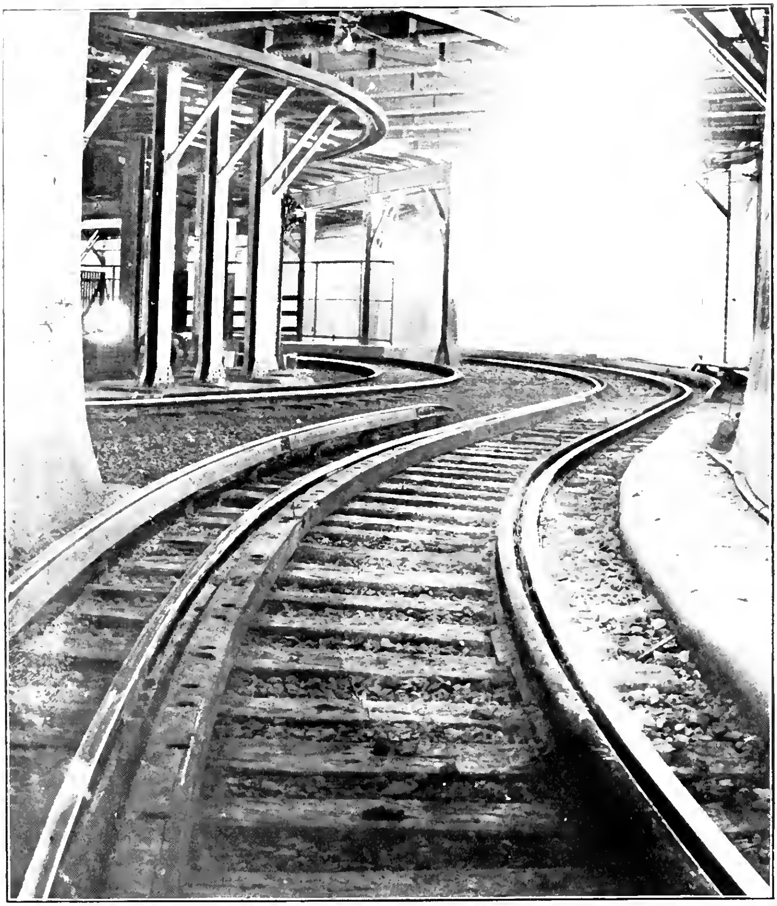
ton Elevated Railway, with which I am connected, has purchased a large quantity of steel rails from time to time. We have not had a very large number of broken rails, but the rails wear very rapidly on our sharp curves. On one curve of 82 ft. radius in the subway the ordinary rail was worn out in 44 days under a heavy traffic, while other harder rails wore a little longer. After several renewals with ordinary rails, it was decided to use a manganese rail, which has been very successful, and has now been in service about six years. I have invited our road master, Harry M. Steward, C. E., to be present this evening, and to speak on this question. He is thoroughly acquainted with the wear of the several kinds of rails on our elevated division. I present a view of the curve in the subway, and also a diagram showing the wear of the ordinary rail and the manganese rail.

Mr. Harry M. Steward. — I cannot say much about broken rails; we do not have many, as our equipment is not as heavy as that on steam railroads.

Mr. Kimball is right about rails not lasting on the Park Street curve. They used to wear out on an average in 44 days, while the manganese steel rail referred to has been in service over six years. This particular manganese rail is not rolled, but cast. I believe, however, there is a movement on foot by various steel companies to roll manganese steel rail, which I understand is a very difficult thing to do. We have been urged to try rolled manganese rail for some time and we hope to do so. I hope it will be found possible to roll such rail, as cast manganese steel is not the best thing that can be produced, for the very reason of its being cast. The wearing qualities are something to be proud of, to be sure, but the price is very high. For instance, rolled rail costs about 38 cents per running foot, while, last year, manganese rail cost us from $6.50 to $9.00 per running foot. This high cost is not so much in the actual worth of the metal as in the finishing of the rails. The rails are cast in about 20 ft. lengths and after being taken out of the molds have to be straightened and then ground to shape. No machine tool, such as a planer, can be used. Grinding is a very slow process, and on account of the labor necessary to shape the rails, the price is very high. If manganese steel rail can be rolled, it can be made use of to a great extent on the Boston Elevated Railway and many similar roads.

Mr. Kimball. — Will the manganese rail resist the side wear the same as the top wear?

Mr. Steward. — We have found that manganese steel will



Boston Subway. Looking South on South-bound Track, just North of Park Street Station.

not withstand side wear as well as top wear. The rolling friction on the top does not seem to have the same effect on the metal as the cutting or grinding friction of the wheel flanges on the side of the rail, and consequently we do not allow the rail to get as much side wear. We protect it, as we do all rails on the outside of curves, by a heavy guard rail which can be greased and which is attached to the inner rail of the curve.

The President. — I would like to ask Mr. Steward if he can give us the chemical composition of that manganese steel.

Mr. Steward. — I cannot tell you the composition, although I understand it is no secret, but there is a secret process in its manufacture which is in the treatment of the steel after it is cast. After the rail has been cast it is reheated in a furnace and quenched at a certain heat. This, and other portions of the treatment, are very carefully guarded. I think that the percentage of manganese is very high, anywhere from 8 to 14 per cent. The other elements are about the same, I think, as ordinary Bessemer or open-hearth rail.

A Member. — Mr. Steward, can you tell us whether the paper on manganese rails which was read before the Street Railway Club is published in their proceedings? The paper was read three or four years ago and dealt with manganese rails. Can you tell us whether it was published?

Mr. Steward. — I believe I read a paper three or four years ago, but not particularly on manganese rails.

Member. — Did Mr. Wharton read a paper?

Mr. Steward. — No, but Mr. Angerer, general manager for the Wharton Company, did.

[Note. — Further discussion on this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by September 15, 1908, for publication in a subsequent number of the Journal.]

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THE SCHOTT SYSTEMS OF CENTRAL STATION HEATING.

BY J. C. HORNUNG.

[Read before the Society, May 15, 1908.]

BY way of introduction of the subject before the Society this evening I will first give a very brief history of central station heating, of both steam and hot water, especially as applied to the art from a practical commercial standpoint.

Steam, under varying pressures, and from various sources, has been used for house warming a great many years, and this kind of steam heating is pretty generally understood, but exhaust steam as applied to the heating of more than one building, or, to speak more correctly, as supplied from a central station, has been in practical use for a period of about thirty years, and then only in a more or less limited way.

The system as brought out about thirty years ago was then known as the Holly System. Limited as was the territory which was then attempted to be covered, many difficulties at once became apparent, principal among which were the loss through the pipes by radiation, the linear expansion and contraction of the pipe lines, due to the wide range of temperatures within the pipes, and the pressures required to produce circulation. All of these difficulties have been overcome; some entirely, and others to a point where they are no longer considered serious.

Heating from a central station by utilizing the exhaust steam and transferring the latent heat units to water, which becomes the heating medium, was first tried on a commercial basis along in the nineties by Homer T. Yaryan, of Toledo, Ohio.

His scheme was simply to conduct the exhaust steam from a reciprocating engine to a surface condenser, thereby transferring the heat to the water, which, by means of pumps, was kept in constant circulation through the radiators. This method called for two pipes of equal size, which were laid side by side in the trench, the one serving as a heat-carrying pipe and the other as a pipe to carry the water back to the plant for reheating. Each building was connected in parallel on the mains similar to the parallel system of commercial lighting of to-day, the drop in temperature due to the house-warming coils being analogous to the drop in potential between the two wires.

About this time a one-pipe system of hot-water heating was brought out which was an enlargement of the systems commonly in use within the buildings; that is, a single pipe belt was run around a block and the various buildings were shunted off the belt similarly to the arc-lighting systems in common use to-day. This system requires that the pipe shall be of the same size throughout the belt, and the number of heat units which can be supplied is determined by the allowable drop in temperature between supply and return ends of belt; as in arc lighting when one belt is loaded an additional belt may be run from the power-house.

In 1897, Mr. W. H. Schott saw the possibilities of central station heating and developed first the *balanced column system* of hot-water heating and a year or two later the *regulated steam system*. From time to time variations from the systems already mentioned have been attempted, but weakness in designs and lack of determination to perfect have caused a withdrawal from the field.

The paper will now take up the Schott Systems, viz., the Balanced Column Hot-Water System and the Regulated Steam System, of which the steam system is at present being installed in Salt Lake City.

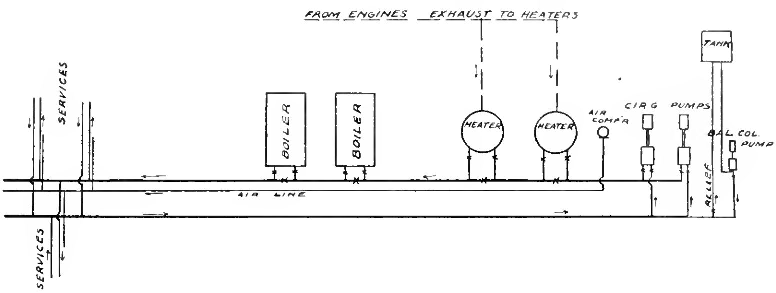
For convenience, and since the fundamental principles were worked out from a water standpoint, we will first consider the hot-water system.

The general station arrangement of this system is shown in a conventional way as indicated by Fig. 1. The exhaust from any steam engine enters the heaters or condensers, which are of the surface type and built in such a manner that the exhaust does not come in contact with the circulating water. As a matter of fact, the condensers do not differ in their functions from a condenser used in a standard condensing power plant, except that

instead of circulating the water through cooling towers, thereby dissipating the heat, we circulate it through house warming coils.

The condensers are usually connected so that no back pressure comes upon the engine, and the water of condensation is handled by a tank receiver pump which delivers it automatically to an overhead tank and from which it again flows by gravity to the feed water heater. An even and accurate supply and temperature of feed water is hereby made possible.

When the situation warrants, a vacuum pump may be placed on the condensers and operated at vacuums which are inversely proportional to the temperature required in the circulating water. Another advantage of this feature, where cooling water may be had during the summer, is that the station equipment of the heating system may be kept in commission throughout the year.



THE SCHOTT "BALANCED COLUMN" HOT WATER SYSTEM.

FIG. 1.

The water of condensation with some make-up water is also used for keeping the distributing system filled, thereby avoiding the annoyance of scaling in the pipes and radiators, which, in the early state of development, was a serious trouble.

The separation of the cylinder oil from the steam is, of course, taken care of before steam enters condensers by the use of efficient oil separators.

The circulating pumps, which are usually of the piston type on a two-pipe system, are automatically controlled on the steam inlet so that a constant pressure is maintained, and, in conjunction with the house temperature controllers, operate to avoid any excess pumpage, which naturally tends toward greater capacity and the elimination of wasted heat units.

Centrifugal pumps of the ordinary type have not been brought into general use on account of varying conditions imposed; that is, varying pressures due to varying loads or elevations and varying quantities of water required due to varying

temperatures. This applies to a two-pipe system and clearly demonstrates that automatic regulation is highly essential where heat is sold on a flat basis and this, by the way, is the only basis for hot-water heating to-day, as no one has so far been able to devise a successful means for measuring this service.

An interesting pumpage chart may be plotted for any given 24 hours. Observation of such chart would show that during the night hours the pumpage is lowest and that during the morning hours, when doors and windows are thrown open, the pumpage increases until about ten o'clock, when it again decreases until evening, when another increase appears. This applies when the outside temperature is normal, but now we have another and much more severe condition to meet, and that is the sudden fluctuation in outside temperatures. Our records show that a drop of 40 degrees in less than one hour is not uncommon, and on such occasions the acceleration in speed of pumps, and incidentally of the firemen, is, indeed, interesting to note.

The efficiency of centrifugal pumps over piston pumps is, of course, fully established, but since the exhaust which has lost none of its latent heat units is at once passed on to the condensers, the net efficiency is not different to any degree.

The boilers as shown are simply the steam boilers employed in any power or electric plant and are connected so that at will they may be converted into circulating boilers. This change requires about twenty minutes, and with it the highest efficiency is obtained, where it is necessary to make up a deficit with coal direct when exhaust is insufficient, due to the fact that boilers operate under low tube and stack temperatures; virtually, they become economizers.

The air compressor is of the locomotive type and supplies approximately 15 lb. of air to the thermostats, which operate the individual temperature controllers placed on each of the several buildings on the line. The detail of these regulators will be taken up later.

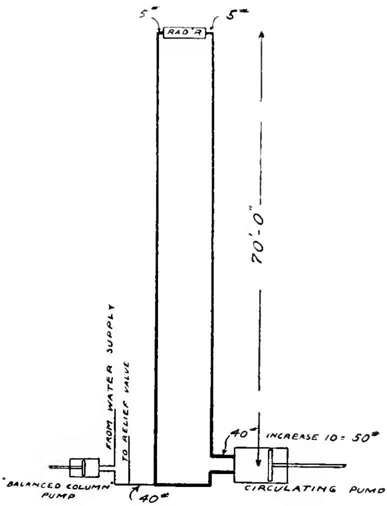
Follow now the circulation from the pumps through the condensers, which may be cut in or out; then to boilers, which may be by-passed or cut in series; then on to the houses which are connected across the mains; water passing through a given house but once before returning to the station for reheating.

The limit of business can at once be seen to be governed entirely by the size of mains and the heat-generating capacity at the station. Distance is governed only by the investor. Two miles distant is not uncommon, and greater distances are prac-

ticable. A drop of 1 degree in temperature in 1 mile of pipe line ordinarily represents the loss.

Following the return pipe back to the station, it will be noted that it connects direct to suction of pump with no other connection save the balance column pump and relief valve.

Fig. 2 shows the principle of the "Balanced Column." Essentially this system is a closed system so that one leg of the pipe line balances the other, and in practice the circulating pumps are required to overcome the friction in the lines only, while the balanced column pump simply maintains the static pressure in the return leg by keeping the system full of water. This item in a tight system is naturally very small.



THE SCHOTT "BALANCED COLUMN" HOT WATER SYSTEM

FIG. 2.

The elevation of 70 ft., as shown, may be in a mile or more of pipe and the "radiator" may represent several hundred thousand feet of radiating surface scattered over a wide territory. The relief valve is usually connected to a branch pipe of small diameter and the discharge flows back into supply tank. This valve operates only when the water expands, due to the rise in the temperature when more heat is required.

Automatic control of temperature in the various buildings is obtained by placing the main control valve in the return pipe just before it leaves the building. The valve is operated by valve stem which is attached to a diaphragm and this in turn is operated by air pressure supplied from the central station. The amount of air supplied, and hence the position of valve stem is controlled by a thermostatic device placed at a convenient place on an inside wall. When the temperature tends to rise above a predetermined point the air is simply allowed by the thermostat to act upon the diaphragm, and when the temperature tends to fall the thermostat relieves the air pressure, allowing the valve to open. Very close regulation is in this way obtained and

according to various tests made the reduction in pumpage will average about 30 per cent.

For practical purposes and to aid in design, a schedule of boiler capacities at varying outside temperatures has been carefully worked out. Take, for instance, 40 degrees above zero, which is an average temperature point, and with water circulating at 150 degrees, a water tube boiler of 100 h. p. rating will handle 36 500 sq. ft. of radiation. A fire tube boiler will handle 31 000 sq. ft. and a surface condenser, using exhaust steam, will handle 19 200 sq. ft. At 0 degrees, which is an average low temperature point, with water circulating at 200 degrees, the machines will handle 20 000, 17 400 and 11 500 sq. ft. respectively. For steam heating the boiler capacities will run from 5 to 6 per cent. less, due to higher tube and stack temperatures.

The amount of radiation which can be carried on any given line depends on a great number of conditions, principal among which are size, length, turns, elevations and class of service. However, in general practice an 8-in. line will carry 52 315 sq. ft. at a water velocity of 250 ft. per ~~second~~ minute and at a loss of 0.5 lb. pressure in 100 ft.

The service pipes for both hot-water and steam heating are usually graded toward the mains and for, say, 2 in. service, 100 ft. long, 3 000 sq. ft. of water radiation can be handled, while the same service for steam will handle 424 sq. ft.

The insulation of the heating mains against loss of heat by radiation is probably the most important feature in connection with the distributing system and hence several schemes have been adopted to limit this loss. Layers of wood with air cells between filled with an adaptable non-conductor have been successfully used for some years. The wood insulation, which is ordinarily of No. 1 hemlock, gives very high efficiencies and under normal conditions a long life. The general tendency now-a-days being toward greatest permanency, a concrete conduit has now been adopted, and with an approved filler, usually of asbestos, properly filled around the pipe, we get an insulation which is absolutely permanent and highly efficient. The insulation proper being largely in the filler, the greater requirements of steam as compared with water are met by leaving more space to fill.

When the soil is wet an effective underdrain is necessary to prevent moisture from coming in contact with pipes, as this undoubtedly has been one of the most serious difficulties in operating a heating plant successfully.

Expansion and contraction of pipe lines during the heating season are factors of interest, since for every 100 ft. of line a travel of at least 2 in. must be allowed for. Taking a Salt Lake block, for instance (792 ft.), we have about 15 in. more pipe in a block in winter than we have in summer. The differences are taken care of with metallic packed joints of special design: for hot water, about 400 ft. apart, and for steam, about 150 ft. apart, each joint being placed in an accessible manhole. In steam practice all fittings and valves are flanged, and services are taken off only at points where fittings are accessible.

Concerning the coal consumption per square foot of radiating surface per hour, per day and per heating season, some very interesting data have been gathered and compiled from many

ERRATUM

Page 38, line 19. For *second* read *minute*.

210°	-20°	275	6[illegible]0	1,452,000	.0437	1049	230.74
200°	-10°	246	5904	1,298,880	.0390	936	205.92
190°	0°	221	5304	1,166,880	0351	.842	185.32
180°	10°	195	4680	1,029,600	.0310	.744	163.68
170°	20°	170	4080	897,600	0270	648	142.56
160°	30°	146	3504	770,880	.0232	556	122.32
155°	35°	136	3264	719,180	0216	518	114.05
150°	40°	124	2976	654,720	.0197	472	103.84
140°	45°	102	2448	538,560	0162	388	85.36
130°	50°	82	1968	432,960	.013	312	68.64
120°	55°	66	1584	355,480	.0104	249	54.78
110°	60°	51	1224	269,280	0081	194	42.68
100°	65°	44	1056	232,320	0070	.168	36.96

Table 3 shows results from Indiana slack, based on a season of 5 280 hours at a net efficiency of 60 per cent. That is, 60 per cent. of the total calorific value of the coal was delivered by the radiator. The radiating surface in this case was the ordinary cast-iron bronzed radiation, mostly of standard heights.

One of the most difficult problems in central station hot-water heating is the accurate determination of the amount of radiation to be set in any given room or building. This is due to the fact that the consumers pay on the number of feet set and

according to various tests made the reduction in pumpage will average about 30 per cent.

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Concerning the coal consumption per square foot of radiating surface per hour, per day and per heating season, some very interesting data have been gathered and compiled from many plants scattered throughout Ohio and Indiana.

TABLE 3.

COAL CONSUMPTION AT VARIOUS TEMPERATURES

SEASON OF 5280 HOURS — INDIANA SLACK COAL · 10500 BTU.

EFFICIENCY = 60% — TEMPERATURE OF ROOM 70°

MEAN TEMPERATURE OF WATER	OUTSIDE TEMPERATURE	HEAT UNITS PER HOUR	HEAT UNITS PER DAY	HEAT UNITS PER SEASON	POUNDS COAL PER HOUR	POUNDS COAL PER DAY	POUNDS COAL PER SEASON
220°	-30°	306	7344	1615680	.047	1.128	248.16
212°	-22°	280	6720	1478,400	.044	1.056	232.32
210°	-20°	275	6600	1,452,000	.0437	1.049	230.74
200°	-10°	246	5904	1,298,880	.0390	.936	205.92
190°	0°	221	5304	1,166,880	.0351	.842	185.32
180°	10°	195	4680	1,029,600	.0310	.744	163.68
170°	20°	170	4080	897,600	.0270	.648	142.56
160°	30°	146	3504	770,880	.0232	.556	122.32
155°	35°	136	3264	719,180	.0216	.518	114.05
150°	40°	124	2976	654,720	.0197	.472	103.84
140°	45°	102	2448	538,560	.0162	.388	85.36
130°	50°	82	1968	432,960	.013	.312	68.64
120°	55°	66	1584	355,480	.0104	.249	54.78
110°	60°	51	1224	269,280	.0081	.194	42.68
100°	65°	44	1056	232,320	.0070	.168	36.96

Table 3 shows results from Indiana slack, based on a season of 5 280 hours at a net efficiency of 60 per cent. That is, 60 per cent. of the total calorific value of the coal was delivered by the radiator. The radiating surface in this case was the ordinary cast-iron bronzed radiation, mostly of standard heights.

One of the most difficult problems in central station hot-water heating is the accurate determination of the amount of radiation to be set in any given room or building. This is due to the fact that the consumers pay on the number of feet set and

the producer must guarantee temperatures. Either a slight excess or insufficiency will naturally cause complaint. The result, however, of this extreme care is satisfactory, since the consumer is given a service which cannot be excelled.

In arriving at radiation requirements some interesting results are obtained, one in particular as concerns the standard cast-iron radiator, viz.: At a mean internal temperature of 170 degrees and an external temperature of 70 degrees the surface will emit 170 B.t.u. per square foot per hour, but for any increase or decrease in mean internal temperatures there is a logarithmic rather than a proportional increase in heat emitted. However, it is possible to plot curves from which, for any given internal temperatures, the heat emitted can be determined. It is also possible to plot curves for heat transmission through glass or exposed walls, and with these data tables may be compiled for any requirements met in commercial practice.

TABLE 4.

CENTRAL STATION COEFFICIENTS "A"

Based upon 6" Water per ☐ Radiation per hour Water entering Radiator at 212° and leaving at 175°. Decorated Radiator emitting 225 B.T.U. per sq ft. per hour, at 70° Mean temperature of Radiator, 190° at 20° below 0.

KIND OF SURFACE		TEMPERATURE OF ROOM							
		55°	60°	65°	70°	75°	80°	85°	90°
Single glass, loose		.58	.64	.69	.73	.77	.81	.85	.90
" tight		.48	.53	.57	.60	.84	.68	.72	.75
Vault light glass		.57	.63	.68	.72	.76	.80	.84	.89
Single skylight		.42	.455	.49	.52	.55	.59	.62	.65
Double		.24	.26	.28	.30	.32	.34	.36	.38
Good Door, ½ Glass		.26	.28	.30	.32	.34	.36	.38	.40
Double Glass (Storm Windows)		.225	.24	.26	.28	.30	.32	.34	.36
Average Frame	N. & W.	.175	.19	.20	.22	.23	.24	.26	.27
"	S. & E.	.16	.175	.18	.20	.21	.22	.24	.25
8" Brick Wall or Well Constructed Frame	N. & W.	.16	.175	.19	.20	.21	.22	.24	.25
	S. & E.	.155	.16	.17	.18	.19	.20	.22	.23
Back Plastered Frame	N. & W.	.13	.14	.15	.16	.17	.18	.19	.20
"	S. & E.	.11	.12	.13	.14	.15	.16	.17	.18
12" Brick Wall	N. & W.	.11	.12	.13	.14	.15	.16	.17	.18
"	S. & E.	.09	.10	.11	.12	.13	.14	.15	.16
17" "	N. & W.	.09	.10	.11	.12	.13	.14	.15	.16
" "	S. & E.	.07	.08	.09	.10	.11	.12	.13	.14
Ordinary Floor or Ceiling		.04	.0425	.045	.048	.05	.053	.057	.06
Fire Proof "		.02	.0225	.025	.0275	.03	.0325	.034	.035

Consider Floor when Basement Piping is covered or Basement is not otherwise heated, and if Basement is not tight add 10% to 25%

Consider Ceiling if Attic is unfloored or otherwise unprotected.

If Rooms or Halls are open to Attic or other open unheated space add 10% to 50%

When Building is exposed to severe winds add 10% to 25%

Multiply by .6 for Steam Systems

To find the radiation required to take care of the cubic contents of a room is largely a matter of judgment on the part of the engineer, as it is wholly a matter of determining how many changes of air per hour may take place, which number of changes may, to some extent, be predetermined, as in mechanically ventilated rooms, but more often, as in residences, it depends

upon the general construction of building and tightness of windows.

Tables 4 and 5 give coefficients for glass, exposed walls and cubic contents which have demonstrated their accuracy.

TABLE 5.

CENTRAL STATION COEFFICIENTS "B"

Based upon 6# of Water per ft of Radiation per hour.
Water entering Radiator at 212° and leaving at 175°.
Decorated Radiator emitting 225 B.T.U per # per hour at 70°
Mean temperature of Radiator, 190° at 20° below 0.

CHANGES OF AIR PER HR	TEMPERATURE OF ROOM							
	55°	60°	65°	70°	75°	80°	85°	90°
½	.003	.0032	.0034	.0037	.0039	.0042	.0043	0045
1	006	0064	.0068	.0075	.0077	.0083	0086	.009
1½	009	.0096	.0102	.011	0115	0125	.0129	0135
2	.012	.0128	.0136	.0146	0154	0166	0172	.018
2½	.015	.016	.0172	0183	0192	.0208	0215	.0225
3	.018	.0192	0206	.0219	.0228	.0249	.0258	027
3½	.021	.0224	0240	0255	.0264	.0291	030	0315
4	.024	0256	0274	0291	.030	0332	.034	036
4½	027	.0288	.0306	.0333	.0351	0378	.0387	.0405
5	.030	.0320	.0340	.0365	.0385	0415	.0430	045
5½	.033	0352	.0374	.0407	0429	.0462	.0473	0495
6	.036	.0384	.0408	0438	0462	0498	.0516	054

Multiply by .6 for Steam Systems

Concerning the steam-heating plant which is at present being installed in Salt Lake City, we have, for generating electrical current, the two-stage vertical turbines taking steam at 150 lb. pressure. The steam for heating purposes is taken from the first stage of the turbines and carried through a 16-in. low-pressure main to a well-established center of distribution which is located in the heart of the commercial district.

The steam passes from turbine to heating main through an automatic regulating valve, specially designed, and capable of adjustment for delivery pressure varying from 0 to the initial pressure, and at such predetermined adjustment will hold the delivery pressure constant regardless of variation in the initial or turbine pressure. Direct from the high-pressure steam header in the station is run a 6 in. line which feeds directly into the center of distribution, and from this center is also carried a small pressure-indicating line back to power house so that the attendant knows at all times what his up-town pressures are.

There is also a high-pressure injector of special design placed in the low-pressure main where it leaves the power house, so that when the turbines are running light a small deficit may be sup-

plied without putting into operation the high-pressure line. This injector is so designed as to put no increased pressure on the turbines. One feature of this system is that the turbines run condensing on the second stage the same as though the first stage had been normally operated.

The condensation after passing through the meters is returned to the station from such territory as lies above the plant. Otherwise it is turned through cooling coils into the sewer.

The regulation of heat in the various buildings is handled the same as for hot water, except that in the case of steam the main controlling valve is placed on the supply pipe as it enters the building.

To meet the growing demands for a more complete service, the Schött Systems have devised their own air valves, condensation meters and low-pressure traps.

The air valve is known as the AUTO-VAC valve and, stated briefly, it allows air to escape from the radiator but no steam or water, and it allows no air to return to the radiator through the valve. In construction it is simply a brass case containing a diaphragm, a check valve and a generous float which floats in water and expands in steam.

The meter is known as the COMBI RECORDING STEAM TRAP, since it acts as a trap as well as a meter. In construction it is a cast-iron case capable of holding 50 lb. of water and a float which simultaneously actuates a pair of valves connected with a walking beam so that one of them is open at all times. When the outlet valve is shut and the inlet valve open, the trap continues to fill until 50 lb. of water have been received. At this point the float actuates the mechanism which instantly reverses the position of valves and the trap operates until 50 lb. have been discharged, when the float again causes the mechanism to put the valves in original position for refilling. Each discharge of 50 lb. of water is recorded on dial placed on outside of meter and this dial reads directly in pounds of water, eliminating the necessity of conversion factors.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by November 1, 1908, for publication in a subsequent number of the JOURNAL.]

POINT BEKA CREVASSE, MISSISSIPPI RIVER RIGHT BANK, PARISH OF ORLEANS, LOUISIANA.

By Frank M. Kerr, Member of the Louisiana Engineering Society.

[Read before the Society July 13, 1908.]

The crevasse of which this paper treats occurred in the public levee on the Point Beka Plantation, in the Parish of Orleans, on the west bank of the Mississippi River, about 15 miles, by river, below Algiers, opposite New Orleans. As the name, Point Beka, indicates, the river bank or batture along there is what is termed and known as a "making bank," and the public levee, located there many years ago, is some distance away from the river bank, as much as 1 000 ft., the batture, or foreshore, intervening between it and the river, being densely overgrown with timber, brush, vines, etc.

The avenues of approach to and communication with the locality where the crevasse occurred were by way of the usual dirt road paralleling the public levee from Algiers down, and by the river. The first, owing to high water, sipage, etc., was slow, uninviting and impracticable for anything like active or extensive approach, and the second, owing to the distance of the levee from the river bank, the timber, etc., afforded no near landing places. No railroads, no telegraph, no telephone, were available. The river was, therefore, as a matter of course, promptly adopted as the most direct means of reaching the locality, one landing being established a mile and a quarter above and another a half a mile below the crevasse.

The levee line at Point Beka, averaging about 10 ft. in height, presented, on the surface, a very good appearance, grade well above the high waters of the past, crown some 8 ft. wide, flat slopes averaging 3 and 3 to 1, and all clean and well turfed. It was, however, known to be infested with crayfish and had become so honeycombed by them as to require constant attention during high water, and the construction from time to time of numerous "mud-boxes," tentative cofferdams, as it were, to surround the apparently worse places in the line. It was at one of these "mud-boxes," constructed a year or so before, that the breach occurred. The crayfish had, no doubt, so chambered the embankment there as to leave it a mere shell, which, notwith-

standing the reinforcement attempted by means of the "mud-box," succumbed to the severe pressure of the high stage of water against it.

The break occurred at about seven o'clock, Saturday, June 6, during the period of high water in the Mississippi River this season, developing a width of about 30 ft. by two o'clock that evening. Steps were the same day promptly taken by the Orleans Levee Board.— the local organization charged with the care, preservation and maintenance of the levees in the Orleans Levee District — to close the break, but without success, the work attempted failing on the night of the 9th, and further efforts were suspended pending developments. After a couple of days' consideration, however, it was determined to make another attempt to close the crevasse, and preparations were at once made to do so.

By Friday, June 12, organization was effected, and the filling of sacks and the construction of the cribbing begun. This was carried on uninterruptedly, day and night, in spite of much inclement weather, and the cribbing completed by noon on the 20th. Sacking followed within an hour after the completion of the cribbing, and by six o'clock the next morning, Sunday, the 21st, the flow through the crevasse, with the exception of the usual leakage common to such work, was checked, the territory back of the breach becoming rapidly relieved of overflow.

The construction of the "mud-box" around the cribbing, with further sacking and the trimming up of the cribs to provide for shrinkage and settling, came next, and the work in its entirety was satisfactorily completed by Thursday, the 25th, no cause for further anxiety for the locality having since developed.

By the time the second attempt to close the crevasse had gotten well under way, the width of the breach in the levee had grown to about 100 ft., beyond which it increased but little up to the closure, being then found, by measurement, to be 109 ft. wide, the upper and lower wings of the work constructed during the first attempt to close the crevasse remaining intact and acting as permeable spurs or dikes, proving an invaluable aid in protecting the exposed ends of the levee from further material loss.

The channel or "gulch" through the levee averaged some 50 ft. in width and from 18 to 20 ft. in depth below the natural surface of the ground, and extended from a point about 150 ft. on the river side of the levee to a point some 250 ft. on the land side of the levee. There was neither time nor opportunity nor

Along Main Line of Levee, below Crevasse.

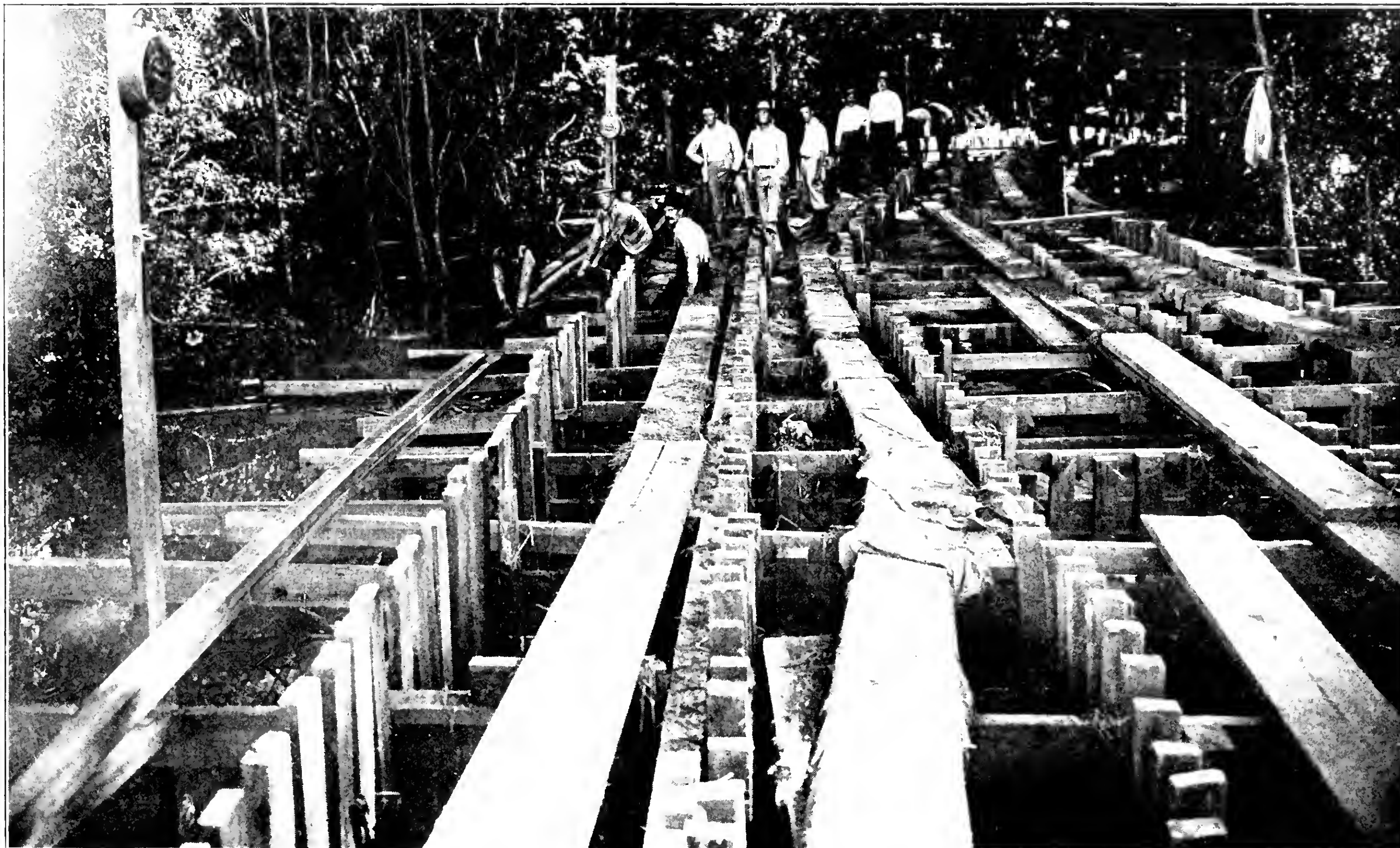
Through the "Channel," or "Gulch."

"Baby," or "Dolly," at Work on Cribbing.

New Work on Second Line, through Timber.


(POINT BEKA CREVASSE)
GULCH AND PART OF WORK ON
FIRST ATTEMPT TO CLOSE CREVASSE,
WHICH FAILED


POINT BEKA CREVASSE.
REAR ELEVATION OF SECTION OF CRIBBING ETC.
(SECOND LINE), NEXT TO LEVEE



Part of Cribbing, Etc., in the Timber.

means of accurately ascertaining the velocity of the current through the break, but it could not have been less than ten miles an hour, and, at times, was possibly as much as fifteen.

Not a single method was adopted or used in closing this crevasse not already fully known to any one familiar with such work. Nothing new whatsoever. *Just* the same old "git-up-and-git" tactics followed by the "Old Timers" of Bayou Lafourche and the Lower Coast in days gone by, only on a much larger and more elaborate scale, and conducted with more system, formulation and deliberation than was possible or needed in olden times.

The most important initial factor in the work of controlling crevasses is an intimate knowledge and appreciation of what one is "up against"; next, organization, dispatch and attention to detail. Time is "king," and must be so recognized — no flurry, or hurry or scurry. Not one moment, however, must be lost in being up and doing, while all question of dollars and cents, that is, cost, must be lost sight of.

Organization means the preparation of bills of material, establishing lines of transportation; depots for receiving materials and supplies; housing and feeding employees and laborers, for day and night shifts; securing a proper division of labor, both superior and inferior, by the establishment of departments, including the selection of proper persons to fill positions, whether superior or inferior, and last, though not least, the direction over all by one general supervisor, whose will and word shall be law.

At Point Beka the greatest drawback was its inaccessibility and the absence of any direct and prompt means of communication with the point of supply, New Orleans. As already explained, the nearest means of direct approach was by river, at landings one and one-quarter and one-half miles, respectively, above and below the breach. From these landings everybody engaged upon the work had to pass to and fro, and everything needed upon the work had to be transported either by hand, by wheelbarrows, trucks and sleds drawn by mules, along the narrow ribbon of earth afforded by the levee, or by small barges or pontoons cordelled along the side of it, the country on both sides of the levee being submerged, and the crown of the levee being but little more than about three feet above the surface of the water.

Large barges, as depots for materials and supplies, and quarter boats for housing and feeding the employees and laborers,

were located at the landings above described, with headquarters in a hastily constructed "shack," as near the breach as safe and practicable. An attempt was at first made to establish a telephone station at "headquarters," but it was found to be an impracticable undertaking, there being no circuit on that side of the river nearer than six miles. However, a station was later secured at a point on the opposite side of the river, which, in connection with a dispatch boat (gasoline launch), did excellent service.

Perhaps the next thing of interest would be some little insight into the bills of materials, transportation and supplies, etc., called for.

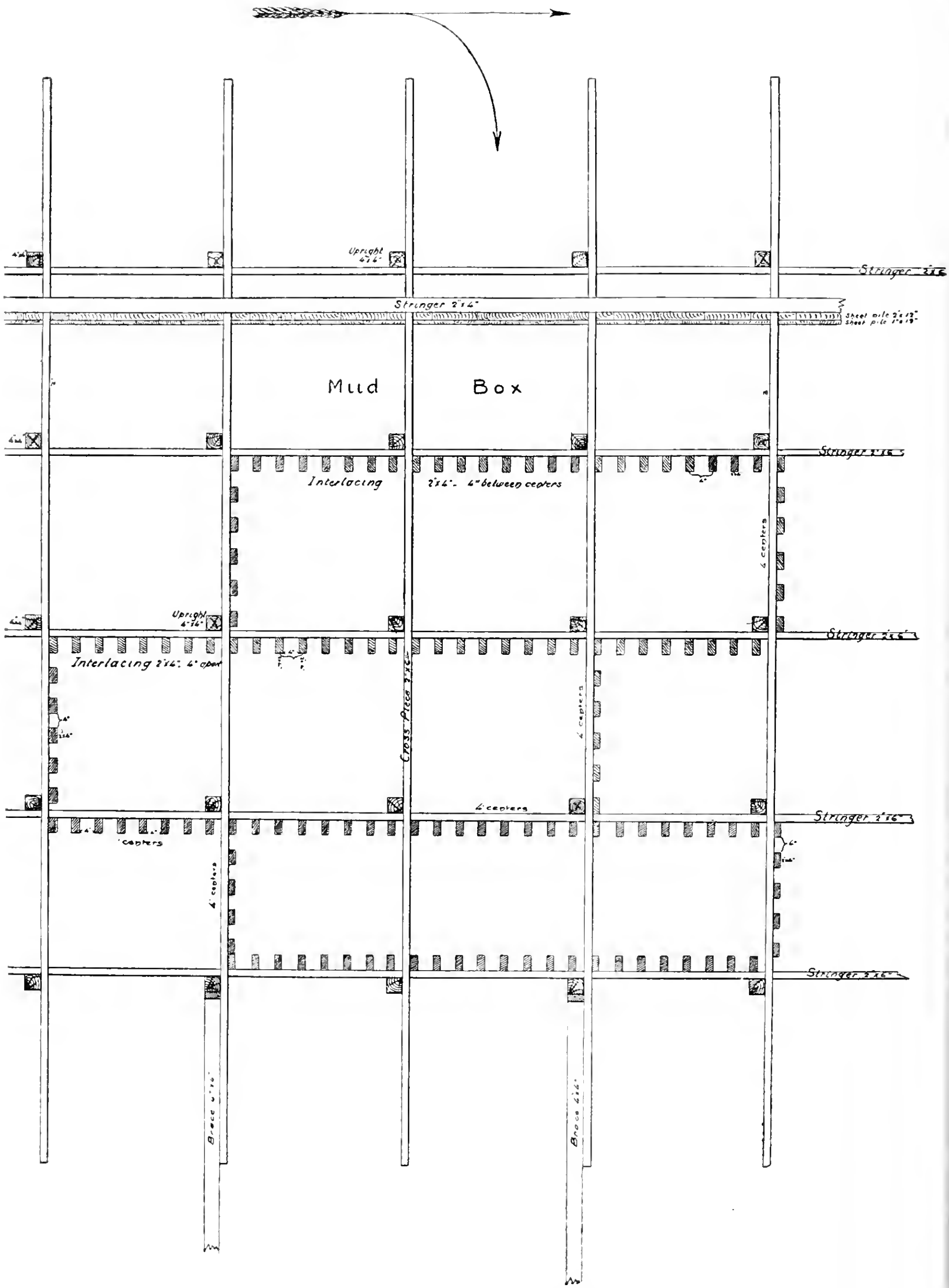
Well, here was the first order, followed, from day to day, by many others: *Materials:* 215 000 feet B. M. of lumber; 65 000 sacks, with twine and needles to suit; 50 kegs of wire nails, 20d. 40d. and 60d.; 50 bales of rice straw; 4 coils of $\frac{5}{8}$ in. manila rope; 4 large tarpaulins; wheelbarrows, long and short handle spades, hand mauls, top mauls, axes, hatchets, adzes, hand and cross cut saws, trucks, gasoline torch lamps, lanterns, locomotive head lights, pine knots, insurance oil, gasoline oil, etc., all "galore." *Transportation:* 2 large harbor tug boats, 4 large model deck barges, 2 large covered barges, 20 small barges or scows, 10 skiffs and 4 large model quarter boats. *Assistants and labor:* one general superintendent of labor and supplies, with full authority to make requisitions for everything necessary for the general comfort and feeding of the whole force on the ground, with as many foremen, stewards, cooks, waiters, scullions, etc., as he deemed necessary; two assistant engineers; four superintendents of sacks; four superintendents of lumber orders; four bridge foremen, with full complement of men for crew for each; and last, but not least, a daily average of about five hundred laborers.

And now about *Construction.* Though very simple, it is difficult to describe it. The sketches and photographs may help out.

The object sought is to subdue the energy of flow by degrees, but with sufficient dispatch to subject the bottom upon which the structure rests to as little scour as possible. Therefore after selecting the route to be followed by the structure, a skeleton, consisting of uprights, stringers and cross pieces, is built around the breach along the route selected, preferably on the river side of the levee in which the breach exists. The uprights are spaced longitudinally and transversely, as conditions and circumstances demand. In the structure at Point Beka, the uprights, 4 in. by 4 in., were spaced 4 ft. from centers each way, the stringers and

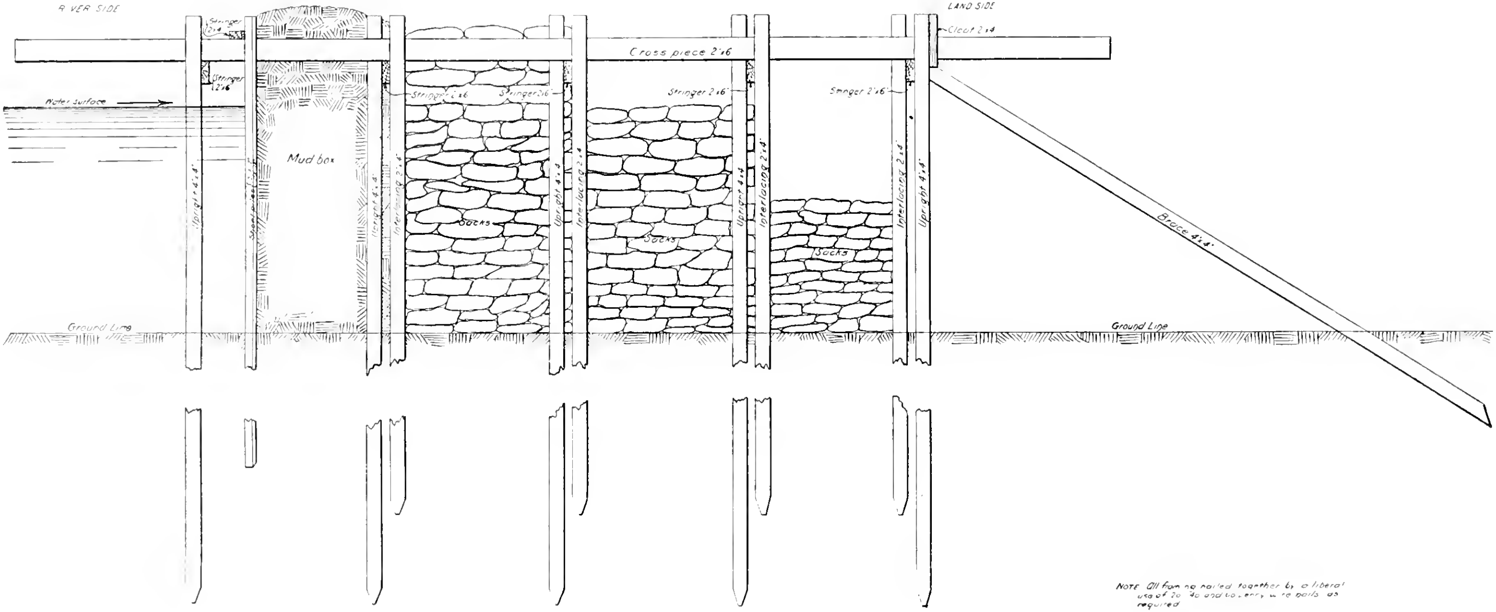
cross pieces being composed of 2 in. by 6 in. Next, the spaces, formed by the rows of uprights, stringers and cross pieces, are interlaced longitudinally and transversely, as shown on plan, with other uprights, usually, as at Point Beka, 2 in. by 4 in., spaced 6 in. between centers longitudinally, and 8 in. between centers transversely, with the narrower face always against the current. The result is a series of cribs breaking joints, as it were, as shown on plan, about 4 ft. wide and 12 ft. long. At Point Beka, the 4 in. by 4 in. uprights were given a penetration of about 8 ft., driven to an elevation about 3 ft. above the water, and the longitudinal stringers were nailed to the uprights, at an elevation of about 2 ft. above the water, with the cross pieces, also nailed to the uprights, immediately above and resting on the longitudinal stringers. The 2 in. by 4 in. interlacing was given about the same penetration as the 4 in. by 4 in. uprights, and driven down as nearly flush with the longitudinal stringers and cross pieces as practicable. All the piling — uprights — was driven by hand pile-drivers, more commonly known as "babies or dollies." (See photograph.) Bracing the structure then followed. At Point Beka this was very simple. A piece of 4 in. by 4 in. driven into the ground on the land side, on a slope of about 3 to 1, fitted and nailed to every other 4 in. by 4 in., with a stiff cleat fitted and nailed above the head of the brace. This quickly adjusted form of bracing is preferable to any kind of interior bracing, as it in no way interferes with the sacking or with the settling of the sacks, as the other is more than apt to do.

As soon as the interlacing is completed, sacking is begun, a sufficient number of sacks to insure no interruption in the progress of the work having in advance been filled and securely closed and sewed up. Right here it should be stated that the sack should not be filled too full, only about three quarters full, to allow for pliability, to induce adjustment to inequalities; and that the thorough tying and sewing of the sacks is very essential. The sacks, of course, were filled with earth borrowed from the levee above and below the breach. The cribs along the land side of the structures are the first to be sacked from end to end. Sacks sufficient only to thoroughly floor these cribs, and to correct any differences of level in the floor, are at first lowered into them. Then the next row of cribs is sacked, from end to end of structure, to a somewhat higher elevation than the first, and the next still higher, until the last row of cribs facing the river side of the structure is reached, in which row of cribs the sacks are brought up to an elevation just above the surface of the water



PLAN OF PART OF CRIBBING.

CROSS-SECTION OF STRUCTURE.



in the river. Then more sacking continues, uninterruptedly, of course, until a safe elevation in each row of cribs is reached, and the flow through the structure is checked, or rather coaxed into submission. Just here a word of explanation about that item of "hay" in the first bill of material mentioned. This is gathered from the bales, by the handful — just the handful — and scattered in the cribs, among the sacks, during the process of sacking, to be borne by the current into the small interstices occasionally occurring between the sacks, and thus temporarily assist in checking small leakages, as may be readily understood.

By the way, too, sacking does not consist of dumping sacks pell-mell, helter-skelter into the water. Not by any means. Each sack should be taken from the shoulder of its carrier and lowered into the water by men assigned to that duty. At Point Beka, a large proportion of the sacks were filled at considerable distances from the cribbing and had to be handled several times before reaching it, — by hand, by wheelbarrows, by sleds drawn by mules and by pontoons cordelled along the levee.

After sacking, the construction of the "mud-box" along the river side of the structure follows. This is usually, as at Point Beka, made about 3 ft. wide, the river wall of the box consisting of a double row of sheeting piling, 2 in. by 12 in., and 1 in. by 12 in., breaking joints, — the 1 in. by 12 in. on the inner side of the wall, — driven to an elevation about 2 ft. above the water in the river, about 3 ft. into the ground, and nailed to a horizontal stringer, 2 in. by 4 in., secured to the cross pieces and uprights, with the cribbing and sacks constituting the land side wall of the box. The box is finally filled up with earth, effectually cutting off all flow, that is, when the structure proves successful.

The form of the structure around the breach was in the shape of a succession of tangents inscribed upon a semicircle having a radius of about 200 ft. The route followed was selected after a careful survey of the batture or foreshore and the depth of water over it, and determined by depth of water, character of bottom and clearings in the timber and brush, — the shallower the water and the clearer the course, the better, as a matter of course. The length of the structure was 741 ft.

Very few mishaps in construction occurred at Beka. Shortly after the work was first completed, some half a dozen "boils" developed on the land side of the structure, two of which, where it crossed old borrow pits, proving for a while quite serious. All were, however, finally successfully treated, and the work as a whole declared, by all who saw it, to present a thoroughly sub-

stantial and workmanlike appearance. The total cost of the work performed, under the direction of the writer, was about $37 500. The damage to property and crops resulting from the crevasse was purely local, probably not exceeding $50 000 actual value. Had the crevasse not been so promptly closed, however, it would beyond doubt have widened and deepened to such an extent as to affect a very large extent of country and to cause damages reaching into the hundred thousands.

Finally, it might be well to say that the gage at New Orleans, at the time of the closure of the crevasse, recorded a stage of 19.8 ft., that is, within a half a foot as high as the highest water of record there. At the same time, too, the water was still rising, reaching the maximum stage for this year, 1908, 20 ft., the day after the closure of the crevasse, or only 0.3 ft. lower than the highest water of previous record. With this stage, the head of water against the completed work stood from 6 to 9 ft.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by November 1, 1908, for publication in a subsequent number of the JOURNAL.]

A SHORT ACCOUNT OF THE LAWRENCE FILTER BEDS.

By Arthur D. Marble, Member of the Boston Society of Civil Engineers.

[Read before the Sanitary Section, June 3, 1908.]

In the late fall of 1875 the water works of Lawrence, which had been in process of construction for two years, were completed and water was turned into the distributing system of the city. Some purification at seasons of high water, when the river carries a large amount of earthy matter, was attempted by the construction of an 8-ft. filter gallery running parallel with the river bank for 300 ft. easterly from the pumping station, but this soon silted up on the river side, and the water was drawn without any actual preliminary purification directly from the river.

Many of our citizens now wonder that the river water was ever selected for our public water supply. The quantity, however, was unfailing, the water soft and good for all sorts of mechanical purposes, and thirty-five years ago scientists considered it all right also for the human mechanism. In 1872 the engineer who reported on the proposed water works said: "One of the most remarkable qualities of running water is that of self-purification," and that "all traces of noxious matter thrown into a running stream have disappeared in the course of a few miles." One chemist who made an analysis of the river water found that opposite the present site of the pumping station it "retained no serious trace of the impurities received at Lowell and above." Professor Appleton said of samples of the river water submitted to him for examination, that the chemical analysis showed "them to be well suited both for domestic and general manufacturing purposes," and the conclusion was that "no city has a better or purer supply of water than has Lawrence." At that time the germ theory of disease played no part in the selection of a public water supply, and we now know that these conclusions regarding the purity of the water were wrong.

It was more than ten years after the completion of the works before any serious apprehension was felt concerning the purity of the water. The report of the Water Board for the year 1888 speaks of the investigations of the State Board of Health which had been going on for more than a year, and states that "their

very able report shows that the water supply of Lawrence ranks favorably with other works of the state." For nearly twenty years we continued to drink the raw river water, loaded with the impurities from the drainage of the large cities above us, and every time that Lowell had an epidemic of typhoid fever, Lawrence followed with a similar epidemic shortly after; and in spite of all the favorable reports to the contrary, I think the bulk of the people have never felt that the river water was, or is now, even after purification, really fit to drink.

In 1891, the State Board of Health, which had been experimenting for a few years with different systems of filtration, had not then recommended any particular one, and the Water Board reported to the city council in favor of installing mechanical filters, at a cost of from fifty to sixty thousand dollars. The report was accepted without reading, and nothing was done. The following year the Water Board determined to do all in its power to satisfy the public demand for pure water by the introduction of some form of filtration. They again sought for advice from the State Board of Health, and on June 5, 1902, that board reported in favor of the uncovered filter bed, which was begun in the early fall of that year and put in commission in September of the following year. This bed I shall refer to in the course of this paper as the " old," in distinction from the " new," which was built in 1906–7. The scheme was the result of experiments made for several years at the State Board of Health Experimental Station in this city, under the direction of Mr. Hiram F. Mills, member of that board, and chief engineer of the Essex Company. Mr. Mills designed the bed, acted as consulting engineer throughout its entire construction, and visited the work nearly every day, all without a cent of expense to the city; and the excellence of our present supply is due to his wisdom and his faith in the certainty of the good results which would follow the installation of his plan.

When first completed the entire surface was undivided, a little unbroken lake, 2.5 acres in area. It was early felt that with our severe winters smaller areas could be cleaned with less peril to the efficiency of the bed, so in 1902 two cross walls of concrete were built, dividing the original bed into three very nearly equal areas. It is now possible to drain and clean one section without exposing the surface of the other two sections to the danger of freezing, and at the same time allow of the filtration of water to nearly two thirds the full capacity of the bed.

From the first the bacterial efficiency of the bed has been

exceedingly gratifying, and its continued and undiminishing efficiency is shown from the fact that while the bacteria have increased in numbers in the river water, there has been no increase in the filtered water. The record of the deaths from typhoid fever is perhaps more interesting than any other feature of the results of the filtration of the Merrimac River water. In the six years immediately preceding the construction of the filter there averaged 43 cases of typhoid fever, with 12 deaths per 10 000 population. In the six years after the construction of the filter the average cases were 15, with 2.6 deaths, a reduction of 65 per cent. in the number of cases and 78 per cent. in the number of deaths. In the first five months of 1892 the typhoid death-rate was seven times that of Boston. It is now about the same as that for the whole state.

As I have already stated, the old bed is about 2.5 acres in area. Both the surface and the bottom of the bed consist of a series of ridges and hollows, spaced about 30 ft. apart. The underdrains are located in the hollows of the bottom, one in each, covered with gravel 1 ft. in depth, graded in five sizes, from 2 in. to 3-16 in. in diameter, the coarsest immediately around the pipe. The gravel is covered with a thin layer of coarse sand, on which the filter sand is placed 5 ft. deep in the sections over the underdrains and 3 ft. deep midway between the underdrains. The section of the sand 10 ft. wide in the center between the underdrains was coarser than the section of sand 20 ft. wide immediately adjacent to and over the underdrains. Through these different grades of sand, and the varying distances, it was expected that the water would travel with about the same degree of purification from all parts of the bed to the underdrains.

The people of Lawrence as a whole have never questioned the wisdom of the construction of the old bed if the use of river water is to be continued. They have, however, questioned the wisdom of being satisfied to always draw from the river, and to quite an extent still question it. Many think that because Lowell was lucky enough to get an abundant quantity of water from driven wells, and abandoned the use of the river water entirely, Lawrence could do the same. They imagine that the ground almost anywhere is full nearly to the brim with water, and all we have to do is to drive wells, and behold, 76 000 people are supplied abundantly! To those who know and realize where the ground water comes from, the problem is far from such a simple affair. Engineers note the location of the ridges of hills surrounding a pond area, and a pretty safe estimate of the amount that pond

will yield can be made. So in every case in the immediate vicinity of Lawrence, where the people were positive a sufficient quantity of water could be secured, the bounds from beyond which the water could not be expected to pass were near at hand, and we felt quite sure our efforts would be as void of satisfactory results as it would be to attempt to supply a family continuously from an ordinary wash basin.

By 1901 the old bed was taxed to its utmost capacity in the winter season, and the need of greater filtering area became startlingly apparent. With the talk of more water, the demands for another source were renewed with vigor. In 1905 we spent nearly the entire season hunting for ground water in localities near enough to the pumping station and reservoir to make both useful in its distribution. And although we spent about $5 800 in this jack-o'-lantern chase, nearly brought the city to a water famine, and although the contractor engaged to drive the wells, who hoped to reap a golden harvest if water in satisfactory quantity and quality were found, pronounced the search useless, I fear many of the citizens of Lawrence think it was a put-up job not to find water, and that driven-well water is here in abundance if we will only make a hopeful hunt for it. I am sure that those engaged in the work at that time would have been only too glad to have secured in this way an adequate or even a limited supplementary supply. Most of the water found contained so much carbonic acid that it would have been unsafe to use through our lead services, and it was consequently condemned by the State Board of Health. This conditon also was unfortunate, for it led many of our citizens to feel that the State Board were bound to continue their experiment (as they considered it) of the use on a large scale of sand-filtered water in a good-sized city, and in that way our filter bed was but a branch of the state experimental station, for which Lawrence was paying the bills.

During the time the city was doing its best to find driven-well water, the Committee on Water Supply of the legislature were striving to make Lawrence undertake something that would surely increase its water supply. But we continued our experiments with driven wells, and another winter came, luckily milder than some previous ones, so conditions at the reservoir did not become as critical as in some previous winters. At one time there was but two days' supply of water in the reservoir, and those in charge of the water department could hardly sleep, fearing that a great conflagration or some other dire calamity would reduce even that quantity to nothing, with the possibility of its

becoming necessary to open the gates direct from the river to the pump well. The people thought that these conditions at the reservoir were purposely aggravated or even manufactured entirely by the Water Board in order to force the construction of a new bed upon the city. They apparently believed that the superintendent, Mr. Collins, was fond of much self-torture, and almost of suicide.

Early in 1906 the city council authorized the loan of $70 000 for the construction of an additional filter bed from plans prepared by Mr. Morris Knowles, of Pittsburg, Pa., a native of Lawrence, at one time member of the Lawrence Water Board, and then, as now, the chief engineer in charge of the construction of the great filtration works of Pittsburg. The order passed with little or no opposition. They had settled down to the conviction that the river water must be used for the present, at least, and that more water must be immediately provided. Indeed, a water famine would have come long ago had it not been for our exceedingly low consumption of only a little over 40 gal. per capita, resulting from the metering of nearly 90 per cent. of the services. A contract for the construction of the filter was let in May to M. O'Mahoney, for more than thirty years a citizen of Lawrence, and for all that time extensively engaged in general contracting work. The estimated total cost of the items of construction contained in the contract was about $47 500. There were some additions made to the original plan during the progress of the work, and the actual total cost of the contract as it stood when accepted by the city was about $49 500. The total cost of the bed complete, including everything, to January 1, 1908, was about $54 300. Since then the water department has done considerable work in grading and finishing the grounds and the surroundings, which should properly be added to the above figures of cost. Although work was begun at the beginning of the summer of 1906 there were some delays which carried its completion into the year 1907, necessitating the purchase of water from Andover and North Andover in the winter of 1906–7, at a cost to the city for the water and the pipe connections of about $10 000.

In April, 1907, when about one third of the roof was in place, a portion of it, having an area of nearly 6 000 sq. ft., which had been constructed in the previous December, fell, destroying most of the roof centering, with about 172 cu. yd. of concrete. The cause of this failure was treated at considerable length in a paper by Mr. Thompson before the New England Water Works

Association in February last, and will soon appear in print in the transactions of that association.* The accident happened while the carpenters were removing the centering. Luckily no one was injured.

The new bed covers an area of about three quarters of an acre. A part of this area was taken out of the river, and a part from the hillside adjoining. The river embankment was first made, the water enclosed thereby being then pumped out. A line of 4-in. sheet piling was driven through the length of this embankment. There were about 35 000 cu. yd. of excavation, costing $11 550. The bed is 21 bays long and 7 wide, the span of the groined arches being 15 ft. between centers of the piers. Manholes in the roof furnish access to the bed, as well as light and ventilation. Large doors at an entrance in the easterly end also admit of access to the bed. The arches at the crown have a depth of 6 in., except under the sand court, where the crown is 9 in. thick, and level on top. The roof under the sand court is also reinforced with twisted steel rods $\frac{3}{4}$ in. in diameter, running both ways, and spaced 9 in. apart. The side walls are 4 and 5 ft. high, from which spring barrel arches to meet the elliptical arches of the roof. These elliptical arches have a rise of 2 ft. 9 in., are generally 6 in. thick at the top, as before stated, and 21 in. thick over the piers. This latter thickness is really much greater, as it was found impossible to prevent the concrete running down into the depression over the piers. The floor consists of inverted arches groined in a manner similar to those of the roof, is 14 in. thick under the piers, and 6 in. in the center between the piers. The piers are 22 in. square, battering below the sand level to 30 in. square at the base.

On the floor is built the main collector, 18 in. by 30 in. in size. It runs in a westerly direction through the entire length of the bed. The walls of the collector were built of concrete in place, and the top covered with slabs of plain concrete 6 in. thick, made elsewhere on the work, and put in place after hardening. Connected with this collector are the lateral drains, running each way from it to within 6 ft. of the sidewalls, in the depression of every bay. These drains consist of half 12-in. pipes, and of 6-in. pipes. On these pipes is placed the gravel, graded in size from a diameter of 3 in. to pea, the coarsest around the pipes, covering the entire bottom of the bed to a depth of 1 ft.

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* See *Journal New England Water Works Association*, Vol. XXII, p. 237, June, 1908.

Above the gravel is the filtering sand 4.5 ft. deep, having an average effective size of from 0.22 to 0.28 of a millimeter. The sand was tested mechanically about five times each day, and continually by a simple test in the bank devised by the State Board of Health when the old filter was constructed, which test determines quickly and in a rough way the fitness of the sand for the work. About two thirds of the sand was washed. The specifications required that not more than 1 per cent. of the sand should be less than 0.13 of a millimeter in diameter. The general run of the bank from which the sand was obtained gave about 4½ per cent. of this size. After washing there still remained from ½ to 1 per cent. About 3 per cent. of the sand was lost in washing, and the sand in the bed shrunk about 4½ per cent. after the water was turned on. None of the sand was left in place after dumping through the manholes, but all was shoveled over. The price bid for the sand was 60 cents per cubic yard. While no accurate data of the actual cost of the sand could be obtained, it is estimated that the sand which did not require washing cost about 56.5 cents in place, and the washed sand about 76.5 cents. After allowing for the shrinkage, which the contractor was not paid for, the above cost became 59 and 80 cents, respectively. The sand in the old bed, carefully selected from veins in the bank, none of which was washed, cost about $1.35 per cubic yard.

The masonry of the new bed was entirely of concrete, mixed in the proportion of 1: 3: 5. The sand and gravel were obtained in part from the excavation for the bed and in part from a bank about 3 200 ft. from the work. The haul to the washers was about 500 ft. shorter. The teams were able to make about nineteen trips a day. Atlas cement was used for the concrete, which stood all the tests called for in the specifications.

The total sand area of the new bed is 31 470 sq. ft., and the cost of the filter bed per sq. ft. was $1.72. The cost of the old bed, which is uncovered and has earth sidewalls and bottom, has been about 87 cents per sq. ft. It is intended to remove the dirty sand from the new bed and replace the cleaned sand by the ejector system through the manholes in the roof and wash and store it on the 90 ft. square concrete court over the middle of the bed.

The water was turned on the new bed in November, 1907, and for two months the water was pumped from the effluent pipe and wasted to the amount of about 1 000 000 gal. per day, until the State Board of Health found the bacterial efficiency

to be such that the water was safe to drink. For two or three months more the amount actually used from the new bed did not exceed 1 000 000 gal. per day. When we began to use the water in January the bacteria numbered something over 100 per cubic centimeter. The number of bacteria in the river varies, but now they number about 4 000 per cubic centimeter. When we first began to pump in November, the effluent from the filter contained more bacteria than the river water, which then numbered about 13 000. The filter was not then ripe for purification work and to the bacteria of the river were added those from the sand.

The bed is supposed to yield a minimum of 2 000 000 gal. per day, which can be increased in time of favorable river conditions to 3 000 000 gal. or more. The estimated available yield from the old bed is 5 000 000 gal., which amount can be increased in favorable times. Mr. Collins, the superintendent of the water works, has in summer time, with a clean bed, got over 6 000 000 gal. from it.

As before stated, Mr. Knowles prepared the plans for the new structure. The engineering department of this city superintended the construction, Mr. Priestman, first assistant in the office, being located almost continuously on the work from beginning to finish. It might be well to state that the engineering department during the past winter has prepared plans for the reconstruction in similar lines of the easterly end of the old filter. The area of this construction will be slightly greater than the new bed just completed. These plans have been formally approved by the State Board of Health, and a contract may be let for its construction another year.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by November 1, 1908, for publication in a subsequent number of the JOURNAL.]

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MODERN PLANTS FOR BUILDING STEEL CARS.

BY HORACE H. LANE, MEMBER OF THE DETROIT ENGINEERING SOCIETY.

[Read before the Society May 15, 1908.]

THE building of steel cars began about ten years ago. From the knowledge I have on the subject, I believe the first work of any consequence was done by the Pressed Steel Car Company, of Pittsburgh. Mr. Chas. Shoen began first to make pressed steel parts, such as stake-pockets, car stakes and corner irons, finally making pressed sills, bolsters, and eventually the entire steel underframe for box cars and an all-steel hopper coal car. These first steel cars were known technically as pressed steel cars because of the fact that many of the parts were pressed into shape. At the present stage of the business many of the steel cars built have very few pressed parts, however. The problem before us to-night is to build a plant which will manufacture cars made either from pressed-up shapes or the regular structural shapes obtainable on the market.

This problem is one that includes a wide range of engineering work. A steel car plant is a shop handling a specific form of structural work. As most of you know, the steel car consists mainly of structural shapes and sheets with a small amount of malleable and steel castings and forgings. In addition to this are the trucks, such as are in every steel or wooden car. The regular steel car of 100 000 lb. capacity weighs from 40 000 to 45 000 lb. In designing a plant to turn out fifty steel cars per day, we must handle approximately 1 100 tons of material each day.

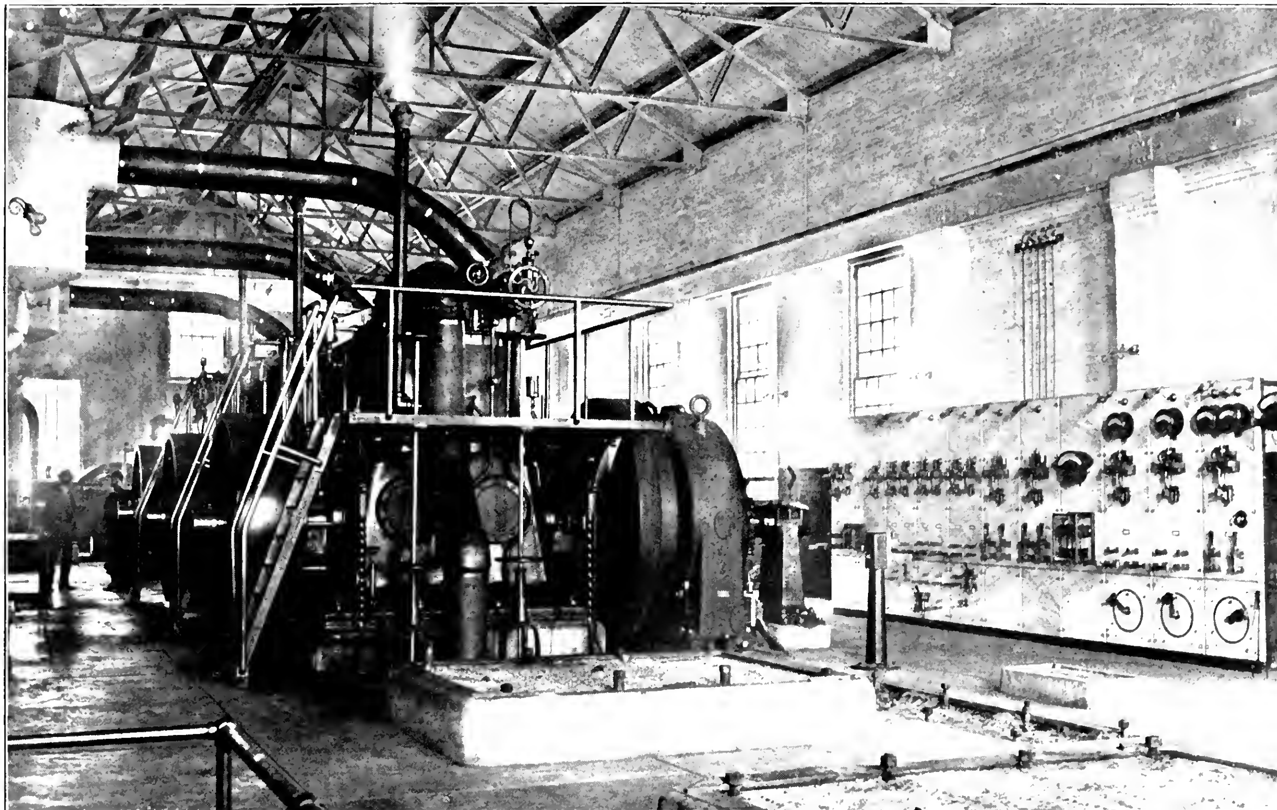
The operations this material goes through may be summed

up as follows: Shearing, punching, pressing, assembling and riveting. To do this rapidly and economically we must lay out this plant so that the material progresses steadily forward from the time it enters as raw material at one end until it emerges as the finished car at the other. We will not discuss the building of the trucks, as that is usually done in another shop. The material we have to handle consists mainly of channels, angles and plates. In addition to this we must handle the draw-bars, bolsters, brake rigging and some smaller parts which go to make up the car.

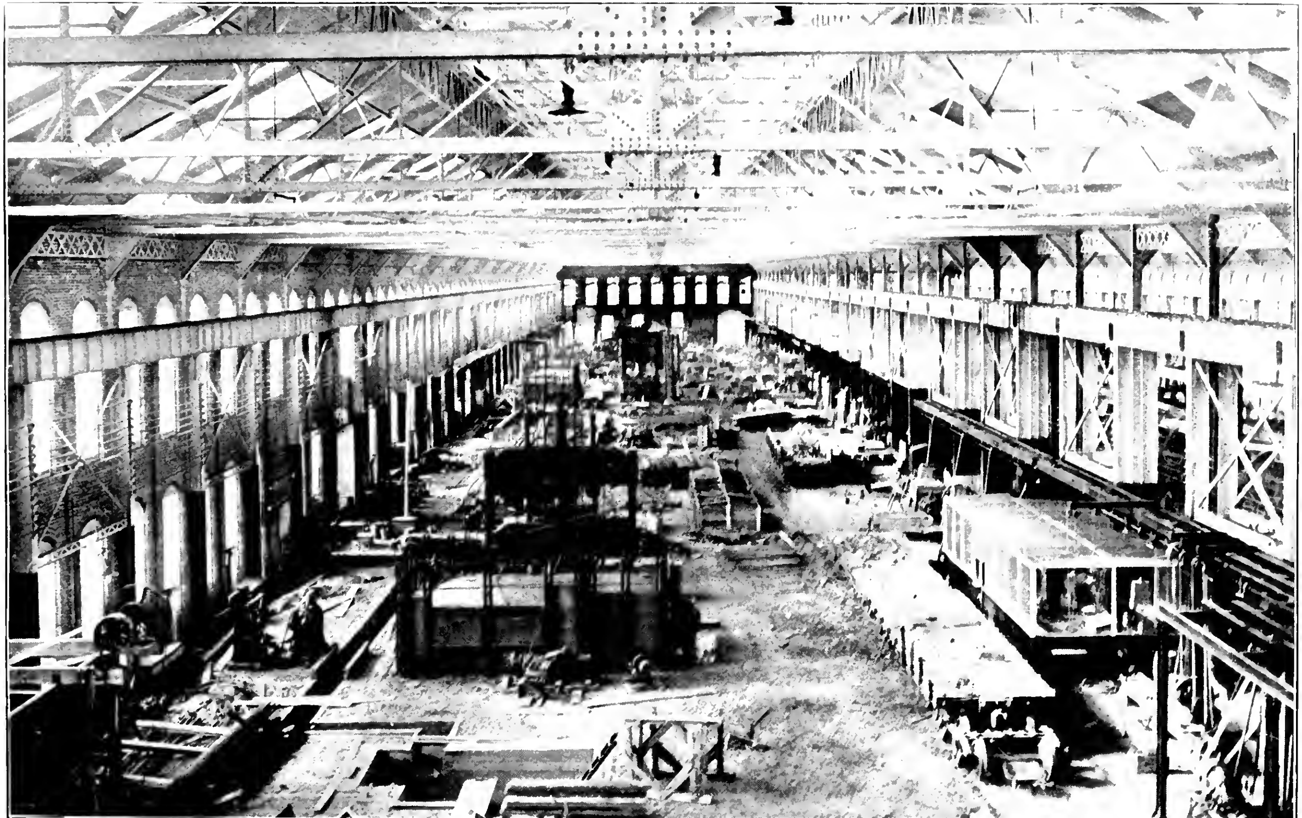
After we have selected the necessary machine tools for performing the operations named, we must next arrange them in the building so that we shall be able to fabricate this material with the least amount of handling, leaving the necessary room between the machines for storing the material being worked without making an unnecessarily large and expensive building, as an excessive amount of space not only means expense of the building and ground, but increases the distance over which much of this material must be carried.

We can probably get a better idea of this matter if we study the arrangement of some of the existing plants which are doing this work. One of the earlier plants was the Pressed Steel Car Plant at McKees Rocks, near Pittsburgh. Although I have been in this plant, I have forgotten the exact dimensions and layout of this building, but as I remember it the plant consisted of two large parallel bays with bays running off at one side, in which the cars were erected. One of the later shops was the Detroit plant of the American Car and Foundry Company. This plant originally consisted of two bays 92 ft. by 780 ft.; 360 ft. have since been added to the eastern span known as the erecting shop. The plant of the American Car and Foundry Company at Berwick, Penn., and also the one at St. Louis, are practically the same size as the one in Detroit; they, however, have more room in their main shop for carbuilding, as they build the trucks in a separate building, known as the truck shop, while in Detroit the truck shop is inside of the main building. A still later building by the Standard Steel Car Company, at Hammond, Ind., consists of two spans, 80 ft. by 1 612 ft. in length.

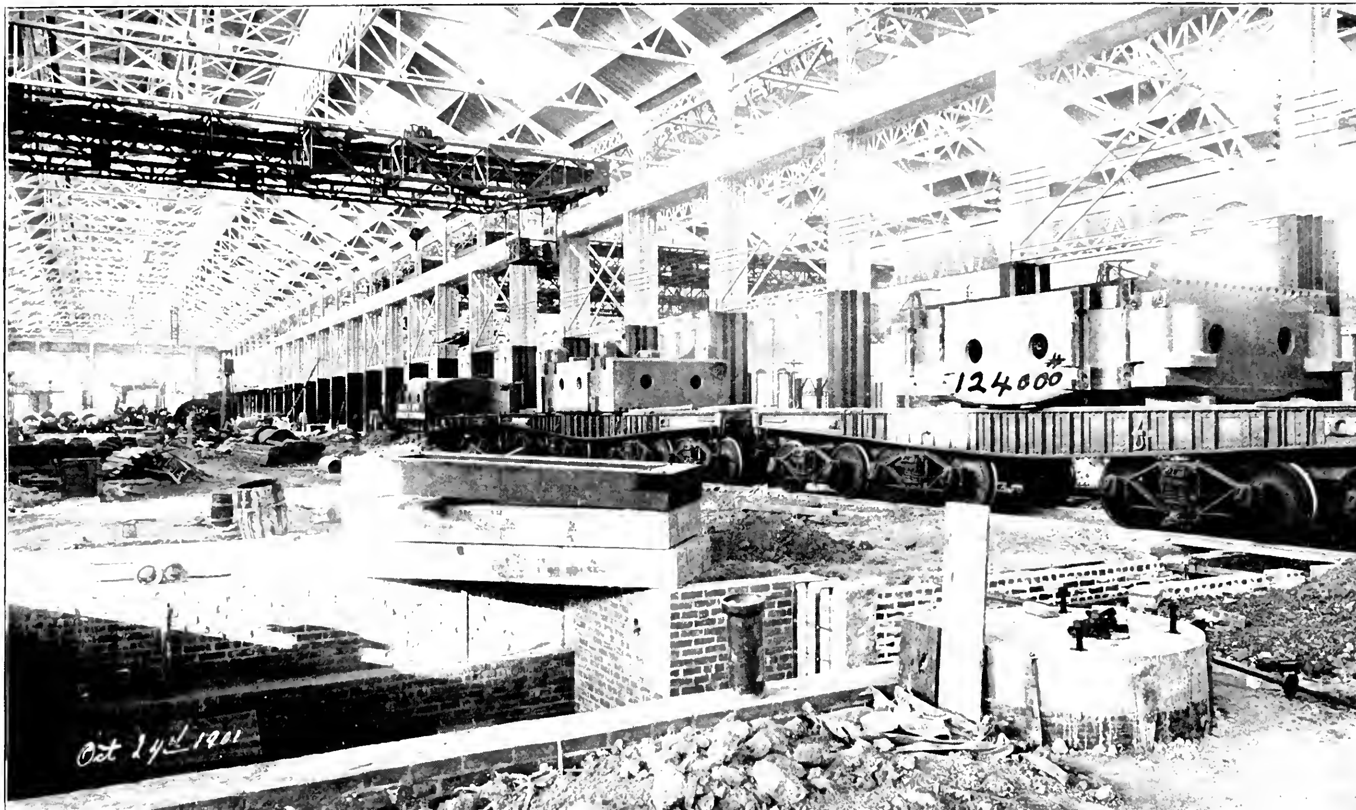
The American Car and Foundry Company have sixteen different plants for building cars; six of these are designed for the building of steel cars. We have some views to present to-night which were taken of their Detroit and Berwick shops; as these shops are very similar, we will give a brief description first of the Detroit plant. The principal tools used are as follows:



American Car and Foundry Company. Engine Room, Berwick, Penn.



American Car and Foundry Company. Main Car Shop, Berwick, Penn.



American Car and Foundry Company. Main Car Shop, Detroit.

American Car and Foundry Company. Pipe Tunnel, Detroit.

Shears.

Four heavy shears, capable of shearing a plate 10 ft. wide and 1 in. thick, also a number of smaller shears of various types including a special angle shear on a turntable so that long angles can be cut at any angle without having to swing them around the shop; that is, the shear is turned so that it stands at an angle to the pile of material, thereby economizing shop room and labor.

Punches.

Four multiple punches capable of punching a row of holes entirely across a plate 10 ft. wide at one stroke of the machine, and of sufficient length to take plates of 50 ft. in length. These machines deserve special mention, as they are self-spacing. There are two levers at the side of the machine (where the operator stands) like the reverse lever on a locomotive and about the same size. These levers have graduated arcs, one being graduated for inches and the other for eighths. By simply throwing these levers the machine will space any distance desired up to 7 in.; in other words, if you have a plate across which you want to punch a row of holes every 7 in., and this plate is started in the machine, with the spacing lever set to 7 in., the machine will automatically feed it through, punching a row of holes every 7 in. If instead of 7 in. you want to make it 4½ or any other number, you simply set the lever to read that way. A great deal of the work put through these machines has various spacings on the same sheet. The operator, keeping his schedule before him, will set these levers to the proper spacing without stopping the machine, so that the plate goes forward automatically, first making a space of 4 in., another of 2½ in. or whatever may be wanted. In addition to this the punches are all arranged with gags so that any punch can be instantly thrown out and the holes omitted wherever it is desired. The operator also has a smaller lever in front by which he can instantly gag all the punches if for any reason he wishes to omit one spacing, or if he should possibly notice before the punches go down that he had made a wrong spacing, he could prevent the punches from doing any work. These gags consist of steel blocks about 2 in. thick, above the punches, which are simply withdrawn so that the punch, instead of going through the sheet, slides up into the socket, or rather the punch and socket both slide up into the upper head or ram of the machine. These machines not only have the advantage of saving an immense amount of labor in marking and punching, but will do the work much more accurately than it is possible to

do it by hand. The American Car and Foundry Company are, I believe, the only car manufacturers who use this type of machine. In addition to these multiple self-spacing punches, there are a variety of both small and large punches, such as will be found in any good structural shop. On some of the larger punches a great deal of special work can be done, such as coping flanges on I-beams or cutting the angles or channels to any special shape desired.

Pressing.

The presses in this shop consists of two 1 000-ton presses and two 500 ton. By 1 000 ton, we mean a press which will exert a pressure of 1 000 tons on the work. Many cars have pressed steel sills. These are pressed cold from plates usually $\frac{1}{2}$ in. thick and perhaps 30 in. wide at the center, tapering down to 18 or 20 in. at the end, these plates, of course, being the full length of the car. This work being too long to be done at one impression, the dies are made in three sections and all three sets of dies are placed on the press at once. The plate is pushed into the press and placed so that one third of it is pressed. It is then pushed in farther and the middle section is pressed and is then pushed on for the third impression, each section of the sheet being pressed to its final shape at one stroke so that after the sheet has been passed through the press it is finished so far as the pressing is concerned. The dies for this work are about the heaviest things to be handled in the shop. The traveling cranes, of which we will speak later, are made heavy enough to handle these dies, which are of cast iron, and which have to be changed every time the press starts on a new lot of work. One of the 500-ton presses is what is known as the flanging press. This press has three cylinders, the main plunger remaining stationary while the two auxiliary plungers push down the clamping bar, holding the sheet in place until the main platen comes down and bends it over. In some cars a great many sheets have the edges flanged at 90 degrees or less according to the design of the car. This work is done on this press. The presses used at this plant all have a fixed lower platen while the upper platen descends on the work. In some other plants presses are used where the upper platen remains stationary and the lower one rises. These are perhaps more particularly adapted to small work. On some of the smaller presses I have seen men insert four pieces simultaneously from all four sides of the press, so that four pieces were pressed at once.

Each of these presses has near it a heating furnace, as most

of the work pressed is heated. The heating furnaces at the large presses are 20 by 30 ft. and will take in any part of a car which needs to be heated. These are reverberatory furnaces, and in the Detroit plant they are fired with soft coal, although in some other plants they are heated with oil. In addition to the above machines there are saws for cutting off I-beams or other special shapes.

There is a variety of other equipment which we cannot enumerate in detail, the truck shop having axle lathes, wheel-borers, arch-bar drills, wheel presses, etc., such as are used in any truck shop. The axle lathes in the Detroit shop are especially heavy modern tools, each driven by its own motor, the Bullock multiple voltage system being used, giving six changes of speed. There is a full machine shop equipment for taking care of the tools, including a heavy planer 10 ft. wide, this being necessary for fitting up the dies used in the presses. There are also four machines for making rivets, two bulldozers for bending arch-bars and upsetting and pressing various parts. There are about thirty rivet fires scattered throughout the plant. These furnaces are heated with oil and have an air blast conveyed through an underground tile pipe system, the air being furnished by blowers direct connected to high-speed motors.

We have now gone over in a general way the operations necessary in preparing this material for assembling and riveting. In a steel hopper car of 100 000 lb. capacity there are about 2 400 rivets to be driven. To be exact, on Pennsylvania hoppers recently built at this plant there were 2 434 rivets, on New York Central gondolas 2 449 rivets, and on Southern hoppers 2 340, so that when this plant was building 100 cars a day, as it was for a considerable time last year, it was driving 240 000 rivets per day, the day including a night shift.

To drive this large number of rivets to the best advantage the material is assembled as far as possible in sections, these sections being riveted on machines especially adapted for each particular work; for example, the whole side of a hopper or gondola car is bolted together with erection bolts and hung from a trolley over the top of a deep-gap riveter. These riveters are 10-ft. gap, and in this plant we have nine of them. The Standard Steel Car Company's shop at Hammond has seven 114 in. gap. These riveters have a heavy U-shaped frame with the open side up, and are placed in a pit so that the rivet being driven is about four feet from the floor. The operator who handles the riveter also has within reach two levers whereby he can raise and

lower the work and also cause it to travel endwise. On a large surface like the side of a car, when handled this way, the rivets can be driven very rapidly, from a dozen to twenty rivets being sometimes put in in a minute, depending, of course, upon the accessibility of the work and the rapidity with which the operator can move it. One man shoves in the rivets, another man operates the machine and moves the work, while usually a couple more men are required to steady the work so as to bring the rivets into position rapidly. Not only car sides, but many other parts, are riveted before the work reaches the erection floor; the sills have the lugs and malleable parts all riveted in the machine before the sill goes to the erecting floor. Bolsters and many other parts of the car are riveted complete in the same manner, much of the smaller work being done on small hydraulic riveters. When the work finally comes to the erecting floor a great many rivets in every car must necessarily be driven with a pneumatic riveter, held in the hand, known in shop parlance as a "Gun." These machines such as you have all seen used in the field on structural work do this work very rapidly, but when a hundred of them are going at once inside a building conversation is necessarily prohibited; even a megaphone would be useless. A fixed hydraulic or pneumatic riveter works so much more rapidly and quietly than the gun that, so far as possible, all work is done on the fixed machines. Some work which cannot be done on the fixed machines is done on the erecting floor with a portable riveter, which carries an air cylinder and heads the rivet at one stroke the same as the fixed machine; the best type has the cylinder attached to a toggle joist so that a small cylinder can exert the necessary pressure. In a great many places, especially in assembling the underframe, these machines can be used efficiently. A portable hydraulic riveter has been tried, but it requires such complicated connections to take care of the supply and return water that it is not practical.

Erection.

We now come to the erection proper; there are two systems used. In some shops a car is erected on a pair of horses and each car is completed in its particular place, that is, one set of men builds the car complete in a fixed place, there being a number of these sets of men according to the size of the shop. The other system might be called the progressive system, whereby the first gang performs a certain operation; the car is then passed along on its own trucks to the next gang and from it to another, in all

about eight or ten gangs being used before the car is completed. This later process is the one used in the Detroit plant and has been very satisfactory. The system as carried on here consists of placing the trucks on the erection floor and at once beginning the erection of the car on these trucks, the center sill being dropped on first, then the cross pieces or body bolsters, then the side sills and so on. The first gang of men simply gets far enough to put on the side sills, usually throwing a short plank across each truck while this is being done. I might also mention that the trucks are shoved closer together than their normal position so that the drawheads can be put in and the men can also get at the rivets over the trucks. This car is then pushed along to the other gangs who do the riveting on the underframe, put in the drawheads and assemble the car through its various stages, the underframe being riveted up before the upper part of the car is erected upon it. The same progressive system is used in the Berwick shops. The Pressed Steel Car Company in Pittsburgh use the other system, building each car on a pair of horses. The Standard Steel Car Company also build their cars on horses. At the Berwick shops this plan was tried for a time, but changed over to the progressive system. There are various points for and against each system, and it might after all be largely a matter of education and training as it is with many other things we have to do with. There are a number of advantages in favor of the progressive; one is that for the same output very much less floor space and shop building are necessary. The material of each particular kind is placed in the exact spot where it will be used; that is, the center sills, for example, would be placed at the first station; each station has only a certain class of material to look after. The men in that gang have only one particular operation to perform on each car and they become very expert in performing that operation. With a few good men in each gang to take the lead, the gangs can be filled in with common help until they are properly evened up. If not properly evened up, the output is undoubtedly limited by the weakest link in the chain. This is the one objection offered to this system, but with the proper supervision I believe that it is not a serious one. With the fixed system all the material for a car must be delivered at each of the stations. More room is required to get all around the car as well as to pile up all the different parts required. One point of advantage in this system is, that if the work is done on a piece work or premium plan, each car can be erected for a fixed price; in other words, the piece-work system is possibly more adaptable where

the cars are built on horses than it is where the progressive system is used. Personally I believe that the progressive is the best, but this may be partly because I have been more closely in touch with it.

We have now followed the material until it has reached the assembled car, and by the time it reaches the end of the shop it is completed ready for painting. Most of these cars receive three coats of paint, but the work is done very rapidly and in good weather can be done out of doors. The Detroit plant, however, has two large paint shops capable of doing this work under cover if necessary. In the winter these shops are kept heated to a fairly high temperature in order to dry the paint as rapidly as possible. You can readily see that in a shop like the Detroit plant, where a few months ago they were turning out a hundred cars per day, to store these cars until three coats of paint were dry requires a very large amount of space. Supposing the cars are painted in three days, we must have room for three hundred cars, or nearly three miles of track.

We have so far not taken up the means of transporting the material around the shop. The eastern span of the Detroit plant carries three traveling cranes, 92 ft. span, 10 tons capacity. These cranes all run on the same track, the crane rail being 40 ft. above the ground. In the western span are two more cranes of the same type and capacity. These cranes travel at a high speed, making 480 ft. per minute, and when the shop is running to its full capacity they are kept extremely busy. As the cranes in each span run on the same track, they cannot, of course, pass each other, and each crane must do the work in its own section or the other cranes must get out of the way. Fortunately the work progresses so in these shops that the cranes seldom have to travel more than one half or one third of the length of the building. We might state here that this entire shop is free from any belting, piping or wires which would obstruct the travel of these cranes.

Each one of the large machines has its own motor attached to it. The only shafting and belting in the building are placed along the side and center columns, and all the piping and wiring are carried in conduits and trenches beneath the floor so that there is nothing in the way to prevent the cranes from sweeping the entire shop. In the new shop of the Standard Steel Car Company there are two sets of cranes, termed the "Local" and "Express." One set runs on a track 23 ft. above the floor and the other set 20 ft. higher up.

In addition to the large cranes in the Detroit shop there are a

multitude of small cranes of various types throughout the shop. Every machine of any size has its own crane, usually simply a mast and jib provided with an air hoist. These in some cases have the jib long enough so that when the material is taken from one machine it can be swung to the next. In this way the material can go forward without the aid of the main crane. On the erecting floor there is a special overhead structure provided with small hoists at each station, so that each gang of men has its own hoist for handling the material. Most of these in the Detroit plant are what are known as "air engines." One thing which we should have mentioned at the outset is the steel yard, adjacent to the main shop, where the material when it comes in is unloaded from the cars and piled up sometimes 30 ft. high. This yard is swept by two more traveling cranes of the same type as those in the shop.

We will now consider the power necessary to operate this plant. A separate power house is built about 40 ft. away from the main shop, near the center, so that the farthest motor is not over 600 ft. from the generator. The power equipment originally installed consisted of 4 Babcock and Wilcox boilers, 300 h. p. each, with an economizer and induced draft apparatus. In the engine room were three Westinghouse vertical compound engines, 18 by 30 by 16, rated 400 h. p. each, direct connected to Westinghouse generators of 250 kw., each 240 volts direct current. Two Worthington compound duplex hydraulic pressure pumps, two Ingersoll air compressors, horizontal two-stage cross-compound, each of 3 000 cu. ft. capacity. In addition to these there is a condensing apparatus consisting of a Worthington barometric condenser with circulating pump, dry vacuum pump and cooling tower, there being no supply of circulating water except the city supply. The steam pressure carried is 160 lb., no superheat. The electrical apparatus is of 220 volts direct current. The hydraulic system carries a pressure of 1 500 lb. per sq. in. and the pneumatic system 100 lb. There is a large air receiver on the pneumatic system and in the hydraulic system there is also a large receiver for the return water, and two steam accumulators with 50 in. steam cylinders and 16-in. rams. These steam accumulators take up very much less space than the weighed accumumulators and are much more lively, the inertia of the moving parts being so much less. Some two years ago this power plant was increased to about twice its former capacity, an overhead coal bin, ash conveyors, four more boilers, another Westinghouse engine and generator, the same as the others, were added. The

hydraulic system was also increased by adding a triple expansion duplex pump, steam cylinders, 22, 34, and 56 in. in diameter, 36 in. stroke, 8½-in. plungers, rated capacity, 600 cu. ft. per minute, this rating being, of course, against a pressure of 1 500 lb. An additional air compressor was put in last year with a capacity of 6 000 cu. ft. of free air per minute, so that practically this plant has been doubled all around over the original design.

There are many minor features of interest in the power house if we had time to go into them. All the machinery is as far as possible automatic, the pneumatic and hydraulic systems being regulated by the pressure on the system. A safety device on the hydraulic system is arranged so that if by chance anything should break in the hydraulic line, the pump will stop.

Transmission.

Transmission of Power from the Power House.—Entirely across the two spans of the large shop is a tunnel 7 ft. high and 5 ft. wide which carries all cables and pipes from the power house into the shop. The electric cables are carried on brackets overhead, while the pipes are carried on the side of the tunnel. The hydraulic supply main is now 8 in. in diameter and the return 10 in. On all of the hydraulic pressure pipe a special joint is used which is made so that the joints are always absolutely tight and can be removed and taken apart at any time in a few minutes. There is a small steam line used to drive two steam hammers and also to furnish heat in the pipe trenches and tunnels. The hydraulic pipe lines after they leave the tunnel are laid in cement trenches covered with plank and a small steam pipe follows them through each of these trenches, so that if the shop is not working nights and Sundays the mains are kept warm enough to prevent freezing. The lighting of this plant has nothing out of the ordinary, two rows of arc lamps being suspended from the roof in each span. These lights are hung every 20 ft. A permanent runway is provided on the lower part of the roof truss to make these accessible for trimming. The side and center columns of the shop also carry arc lamps, as well as some of the larger machines. In addition to these a large number of incandescent lamps are used around the smaller machines, many of them being attached to flexible conduits so that the operator can push them around to the most suitable position.

Heating and Ventilating.

As this shop covers four acres and is 40 ft. high at the eaves,

it requires a good-sized heating apparatus to take care of it. There is a platform 25 ft. above the floor at the north end, on which are placed several stacks of hot-water radiation having a total of 15 000 ft. of surface. These practically form three sides of a room. On the fourth side there are two large exhaust fans which draw the air from the shop through these radiators and deliver it in galvanized iron pipes to all points of the shop, the main pipe being 60 in. in diameter. The radiators are heated by hot water from the power house. The exhaust steam from the main engines of the power house is passed through a large hot-water heater, and a small Westinghouse engine direct connected to a centrifugal pump causes the water to circulate from the heater to the radiators and back to the heater. The mains carrying this water are 5 in. in diameter. The temperature in these radiators can be carried very close to the boiling point if the weather demands it, or can be carried at as low a temperature as desired, as all the engines are arranged to run either condensing or non-condensing. In addition to the exhaust steam there is a live steam connection controlled by a thermostat. This thermostat can be set to any temperature desired in the heater so that the operating engineer can with two fingers turn the thermostat and change the temperature of the whole shop, or he can set the thermostat as may be required according to the weather. This is an excellent system and practically it works out well except that when three or four doors are open every few minutes, each one of these being big enough to allow a locomotive to pass in and out, and the weather is extremely cold, there may be complaints that the apparatus is not doing its work. Of course, every time a finished car goes out, which occurs every eight minutes, the door is opened and the locomotive takes it away. There is also a supply track where a locomotive comes in to provide raw material, and in addition to these there are a number of small doors and two supply tracks where material is pushed in by hand. Of course these all affect the heat of the shop. There are also more than 1 000 tons of material brought in from out of doors each day which will absorb heat until it comes up to the temperature of the shop. In addition there are ventilators along the entire length of each span, many of which are usually kept open to let off the gas from the rivet furnaces, there being all together twenty-four furnaces consuming oil, and as these have no chimneys the products of combustion rise in the shop. Fortunately these furnaces give out a great deal of heat so that in the winter, even with the opening of the ventilators

and doors, the heating apparatus is usually shut off from eight o'clock in the morning to perhaps five in the afternoon, the heat from the riveting furnaces and other heating furnaces as well as the other hot material throughout the shop being ample to keep it in a very comfortable condition during the day. The heating apparatus is usually run at night, especially if the shop is not working up to its full capacity.

Although the business of steel car building is now practically at a standstill, it has gone forward with very rapid strides with the last few years. The demand for cars of larger capacity and greater endurance has on many roads put the wooden car practically out of service. Although there are at this time 413 000 freight cars on sidings in this country out of service, with the resumption of business there will again be the cry for more cars, and many of these on the sidings are cars that will only be used when better cars are not available. One great field in steel car building has only just been opened up. I refer to steel passenger cars. One of the first orders for steel passenger cars was for the ones used in the New York subway. These were built by the American Car and Foundry Company, in their Berwick plant. Since then quite a few steel passenger cars have been built at this plant. They are now building some magnificent all-steel passenger cars which are 84 ft. in length. This work requires different equipment, a shop differently laid out and a different class of help. Some other shops are now building steel passenger cars. In some cases the railroads themselves have attempted this work. The beginning of every business is costly, and these first large steel passenger cars have been costly; however, we shall soon see shops properly equipped and designed for this work, and the day for the wooden passenger coach as well as the wooden freight car will be soon ended.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by December 15, 1908, for publication in a subsequent number of the JOURNAL.]

THE WATER SUPPLY OF SAN FRANCISCO, CAL.

By C. E. Grunsky, Member of the Technical Society of the Pacific Coast.

[Read before the Society, August 28, 1908.]

Very early in his connection with the affairs of San Francisco, the writer reached the conclusion that the water works of the city should be municipally owned and that the water works as now in service should form the nucleus of the municipally owned system. Without reviewing the entire water supply question, a few remarks on this phase of San Francisco's water supply problems may be acceptable to the society and may also be of some service to the municipality.

It must be remembered, in the first place, that under the constitution of the state of California it is made the duty of the board of supervisors of the city and county of San Francisco to fix water rates, that is to say, to fix the maximum permissible rates, which are to remain in force for one year and no longer. These rates, according to law, as interpreted by the courts, must be such that they will yield a reasonable return on the value of the properties in actual use. No one has yet laid down a rule, acceptable to both municipality and water company, that can be followed in the determination of the value which should be made the basis of the rate fixing. There is great divergence of opinion as to the items that should be included in a valuation and as to the weight that should be given to different methods of valuation. The boards of supervisors have at times been under suspicion of favoring the water company by fixing rates high; at other times the rates established have been so unsatisfactory to the water company that the courts have been resorted to for relief. The annual recurrence of proceedings for fixing rates is a great embarrassment to any public service corporation. It makes the profits of the business more or less uncertain, particularly as injustice may result from ignorance, or prejudice, or from failure of the legislator to appreciate the high moral obligation of being just to the public service corporation as well as to the people. It is not surprising under this system of fixing rates annually that the public service corporation should have been suspected at times of pernicious political activity, or of attempts to bribe public officials.

It would be better if rates subject to review by the courts were fixed for longer periods than one year. Five years would seem a reasonable time for which to assure an income that will encourage the maintenance of good service. In every case of rate fixing full consideration should be given to the facts that called the public service corporation into being, it being generally true that the municipality was in need of the service rendered and was not ready to undertake the construction of municipal works, but was dependent upon private enterprises, which often involved unusual business hazard. This situation is very different from that occasionally presented of a rival concern, duplicating established works, perhaps forcing a combination, but at any rate being in the field only because the prospect of a profit was good.

Under the law as it stands the water company is slow to expand its works. New sources of supply are added only under the compulsion of dire necessity, and sources of water of doubtful reliability are continued in service as long as the municipality will tolerate them. The present status in San Francisco cannot be maintained indefinitely. Either assurance must be given to the water company that it may continue to do business on a fair basis or the city must acquire water works. The first steps on the latter course have already been taken; the supervisors have declared their intention to acquire water works and have asked for propositions to sell established works to the city.

The City Engineer's Presentation of the Problem in Successive Reports.

As city engineer from 1900 to 1904, it was the duty of the writer to investigate the sources of water from which San Francisco might be adequately supplied. Section 1 of Article 12 of the charter of the city and county of San Francisco provides:

"Within one year from the date upon which this charter shall go into effect, and at least every two years thereafter until the object expressed in this provision shall have been fully attained, the supervisors must procure through the city engineer plans and estimates of the actual cost of the original construction and completion by the city and county of water works . . . and such other public utilities as the supervisors or the people by petition to the board may designate."

Acting under instructions of the board of supervisors and of the board of public works a progress report was submitted by the writer on the water supply investigation under date of August 12, 1901. (Municipal Reports of San Francisco, 1900–1901.)

The following extracts from that report relate to the possibility of making the works of the Spring Valley Water Company a part of any municipally owned water works.

"The combination of some new project having its source of supply in the Sierra Nevada Mountains, with the established system, is a possibility which may ultimately come up for consideration, because the most available nearby storage is already utilized. The Spring Valley Water Works has occupied the most available sites for receiving and service reservoirs, and has an established distributing system and an established business.

"There is no reason why these advantages should not be recognized and why the city should not avail itself thereof, if suitable financial arrangements [terms] can be made [agreed upon].

"For the present, however, as a basis for a cost estimate of water works, it is necessary to proceed on the assumption that a new and independent system is required, and the various projects are considered primarily from this standpoint. Should a combination with the established system be found advisable, then the main alteration will relate to conduit capacity, as it would, in such event, not be necessary to at once put into service two pipe lines, each with a capacity of 30 000 000 gal. per day — a single pipe line would suffice. The pipe line would not terminate in San Francisco, but at Crystal Springs reservoir.

"It is desirable that the combined sources of water supply for this city should be capable of yielding ultimately at least 120 000 000 gal. per day, and that any source of supply now to be utilized, or an extension of the established system, should place at least 60,000 000 gal. of water per day at the disposal of the city and that the capacity of water works should be such as to deliver this amount of water to the city at the outset. Any new source to be combined with the established system should be capable of yielding at least 30 000 000 gal. per day and a possible expansion to 90 000 000 gal. is desirable.

"Under an operation of the Spring Valley Water Works, in conjunction with a Sierra supply, a better water than now furnished is to be anticipated, because the peninsula reservoirs could be kept full and ill-effects of low-water stages with exposed flat marginal areas would be minimized. . . .

"Water works now acquired or constructed by the municipality should serve the city for all time. They should be such that other works with Sierra Nevada sources of supply can, whenever required, be combined with them."

On July 28, 1902, a final report was submitted by me as city engineer on the Tuolumne River project for supplying water to San Francisco. (Municipal Reports of San Francisco, 1903-1904.) The following quotations are from that report.

"This project is submitted in compliance with directions of the board of public works as authorized by the board of

supervisors under charter requirements. It is not to be inferred, however, that the city engineer desires to recommend, in submitting this report and a cost estimate, the original construction of an entirely independent water works system as here outlined.

"It must be manifest that such procedure would render valueless certain properties of the Spring Valley Water Works now used in supplying water to this city. As some of these properties can be incorporated in the proposed system to advantage, no other conclusion can be reached than that the interests of the city and of the Spring Valley Water Works are mutual — to have the established works in part, at least, retained in service, and to have the new works supplement that part of the Spring Valley Water Works system which can be thus retained in use. This fact should not be lost sight of in negotiating for the established works as required by law.

"Enough has been said to show that there is no more available source of supply of first quality water with which to supplement the supply of the Spring Valley Water Works than that herein reported upon. Treated from the standpoint of a supplemental supply, however, it should be remembered that the delivery of surplus water would then be into Crystal Springs reservoir instead of into a new reservoir at Belmont, and that a single pipe line with a capacity of 30 000 000 gal. per day would fully meet all immediate requirements. . . .

"The city distributing system would come into use without modification, except the placing of larger mains in some sections of the city to insure the best possible fire protection and the construction of new reservoirs and tanks and an improvement of the pumping facilities. It is thought that an expenditure of $1 000 000 in betterments of this kind would be at once justified if the Spring Valley Water Works' supply were augmented by a supply from the Sierra Nevada Mountains, and that about $500 000 would cover the cost of the receiving reservoir at the House of Refuge lot, and its service mains.

"The appraisements made from time to time of the value of the Spring Valley Water Works properties, as a basis for fixing water rates, may serve as a preliminary guide in determining the financial aspect of such a combination system.

"Should it be carried out, then the conditions under which the nearby sources serve can be materially improved. The Crystal Springs reservoir and Lake Merced can be filled with Sierra Nevada water and kept full. The former will be drawn upon only to the extent of the annual yield or even less, so that less variation in quality of water than at present is to be anticipated."

The availability of various sources of water for use in San Francisco after discussion by the writer as city engineer in the reports already referred to of August 12, 1901, and of July 28, 1902, was further dealt with in a report dated November 24,

1902. (Municipal Reports of San Francisco, 1903–1904.) Extracts from this report relating to the Spring Valley Water Works follow.

" The essential facts relating to the Spring Valley Water Works system and its sources of supply have already been presented in the progress report of 1901. These established works cannot be ignored when an earnest move is made toward the acquisition by the city of municipal water works. In their entirety they are comparable with the other projects that are or have been under consideration.

" No proposal has been submitted for a sale of the properties of the Spring Valley Water Works or any portion thereof to the city, and no definite project for the acquisition thereof has yet been formulated. Such a project would necessarily differ materially in some of the most important features of water works from the other projects under discussion. In the first place, the works have the advantage of being already constructed and in actual use. They are supplying between 25 000 000 and 30 000 000 gal. of water per day. Their distributing system, which, with its 400 miles of pipe, reaches every important establishment in the city, and from which some 50 000 private services are supplied, will either come into use with some other project, or it must be practically duplicated in case that it be not made a part of the municipal system. Other portions of their works, even though their water sources be ignored, would still be valuable to safeguard the supply from distant sources. In the second place the sources of water utilized by the Spring Valley Water Works are near at home. The advantage of short lines of conduits is in a large measure, however, offset by the disadvantage of widely scattered works and the necessity for taking unusual precautions to prevent the pollution of the waters. In the third place, these works can be acquired only after negotiation with present owners and agreement upon a price.

. . . .

" It appears from what has been said in the foregoing pages and the earlier reports herein referred to that the Spring Valley Water Works system, to the extent of its capacity, ranks first in the reliability of service; that the Tuolumne River project ranks highest in the quality and quantity of water; that in the matter of first cost to the city, the advantage should be in favor of the Spring Valley system (a sale at a fair price is to be assumed).

" It is to be added that in the matter of operation it remains uncertain which system, the Tuolumne River project or the Spring Valley Water Works, would have the advantage — the probability being in favor of the newer system.

" Under a combination of these two projects, only a part of the Spring Valley Water Works' properties would be required. Whether such combination would prove of advantage to the city cannot well be determined in advance of an agreement upon the

price at which the necessary parts of the established system could be acquired."

On the occasion of a farewell banquet tendered by citizens of San Francisco to the writer upon his appointment as a member of the Panama Canal Commission, he found opportunity to say in reference to the water supply of San Francisco:

"San Francisco is the only city of its size in the United States which does not own its water works.

"There is no question in my mind that water works municipally owned would be well managed, would enable a reduction of water rates for the same service rendered and would enable the city to provide for its inhabitants the best and purest water obtainable from any source.

"Half a century is but a short time in the life of a city. Looking into the future fifty years, we see in place of our present city a magnificent metropolis—the upper end of our peninsula from bay to ocean densely covered with buildings; the population increased to over one million; Oakland, Berkeley and Alameda clamoring to become a part of San Francisco, if they have not already been made a part thereof; and for this city of the future it is now time to plan the water works, nothing being so essential to the health and comfort of the inhabitants as an abundant supply of pure water.

"In thus looking ahead, it has become apparent to those who have carefully studied the matter that the ultimate source of supply for our water must be in the high Sierra Nevada Mountains. The steps that have been taken to secure water from these mountains is known to all and need not be repeated. Legislation is now pending in Congress which may give to San Francisco the source of supply which comes nearest to being ideal. Whether the project for municipal water works based upon such a source must be carried out at once as an independent project or whether the same must be combined with the present system is the question which will, in the near future, confront the people of this city; but whatever the source of the water, the water works should be municipally owned. The sooner this is brought about the better for the city. Until then the annual trouble and annoyance of fixing the rates to be charged by private corporations will continue, and ill feeling will be engendered between municipal authorities and the officers of the water corporation, and the service cannot be expected to be such as would be rendered under municipal ownership.

"No private corporation can ever do as well for the public, as long as its efforts are being continually discredited and its income is uncertain, as could be done by a competent water department of the municipality. Of all questions relating to municipal ownership of public utilities, none is of such importance, none so urgently pressing, as that of the ownership of the water works. The obstacles which at the present time seem to

be in the way of securing from the federal authorities the reservoir rights of way in a forest reservation, as asked for, are probably not as great as appears on the surface. The main opposition comes apparently from the irrigation districts which are dependent upon water from the Tuolumne River. These districts are not now in a position financially to increase the flow of water into their canals by means of storage in the high mountains. They look forward, however, to the time when the increasing areas under cultivation, the increasing demand for water which will be necessary for irrigation, will make storage in the high mountains desirable. These districts at the present time look with alarm upon the taking of any water from the Tuolumne River for the benefit of San Francisco. As a matter of fact, however, the water to be taken by San Francisco is not water which would be of any benefit to the districts, being only a small portion of the waste flood waters of the river which now flow unused to the sea.

"San Francisco would, then, be depriving the districts of nothing except merely of the opportunity to store water for their own use when the time for such storage shall have come, in those two particular reservoir sites for which San Francisco has made application. To these reservoir sites San Francisco has as good a right as any person or any other section of the state. San Francisco has made the first application for them and San Francisco must take every step necessary from time to time to protect her rights and to be allowed to use these storage sites for the impounding of water if such storage be ever permitted in the forest reservation. But the flood waters impounded when the storage works shall have been completed will for many years — from a quarter to half a century — be far in excess of the amount actually required to supply the needs of San Francisco and her inhabitants.

"There will be a large surplus of water in the reservoirs, and this surplus can be liberated at times when it will be of greatest benefit to the lands in San Joaquin valley upon both sides of Tuolumne River requiring irrigation. It is to be anticipated that in these irrigated districts the soils will gradually become saturated with water, and after a number of years the water required per acre irrigated will gradually decrease. At the same time the districts will be decreasing their bonded indebtedness and the time will come when they will feel financially able to carry out storage works of their own, and then they, like San Francisco, will be compelled to apply for the privilege of utilizing storage sites in the forest reservation.

"When this situation is thoroughly understood by the irrigation districts, instead of opposition, San Francisco should receive their help.

"The more thoroughly the available sources of water supply are investigated, the more it will become apparent that the solution of the water question lies along the lines that have been indicated and that the time has come for determining to what

extent the established water works are to enter into the ultimate water supply project. I trust that the day may not be far distant when the municipal ownership of water works will be an accomplished fact."

Acquiring Control of the Reservoir Sites on Tuolumne River.

Among the sites for the storage of water in the Sierra Nevada Mountains which have been examined and reported upon by the engineers of the United States Geological Survey are Lake Eleanor and the Hetch Hetchy Valley. Both of these reservoir sites are in the watershed of Tuolumne River. The latter is on the main stream. Writing of this reservoir site in the twenty-first annual report of the Geological Survey, Mr. J. B. Lippincott, of Los Angeles, then the assistant in charge of the hydrographic work of the Survey in California says:

"The valley proper is about three and one-half miles long and of a width varying from one quarter to three quarters of a mile. The rugged granite walls, crowned with domes, towers, spires and battlements, seem to rise almost perpendicularly upon all sides to a height of 2 500 ft. above this beautiful emerald meadow. . . . It was visited in May when the snows on the glacier meadows on the higher altitudes were rapidly melting, and the river was bank full and overflowing the lower part of the valley. The water is here dammed up, owing to the narrow outlet between high mountains of granite rock."

The Tuolumne River, as a source of water for San Francisco, with Lake Eleanor and Hetch Hetchy Valley as reservoir sites, was investigated preliminarily and reported upon by the city engineer in 1900. In January, 1901, the first step was taken toward acquiring reservoir rights-of-way in the watershed of Tuolumne River. The following extracts are from a communication addressed by the writer, at that time city engineer, to the board of public works, under date of January 23, 1901.

"The water supply investigation has been advanced sufficiently to justify the conclusion that San Francisco will ultimately be in need of a source of water from the Sierra Nevada Mountains either with or without the utilization of the established works and nearer sources. Preliminary examinations demonstrate the practicability of bringing in a supply from such a source.

"Under these circumstances the acquiring of the necessary water rights and storage facilities should not be overlooked. They should be secured as opportunity offers to the end that when the time comes works may be established adequate to meet the future needs of this city.

"To prevent certain privileges and rights that may be of vital importance from falling into the hands of speculators, private individuals or private corporations adverse to the interests of this city, and as the regulations of the Department of the Interior permit the filing of applications and the setting apart to individuals or corporations of reservoir sites in the public domain, application should at once be made to the Secretary of the Interior to set apart for the use of this city the Hetch Hetchy Valley and Lake Eleanor reservoir sites."

Applications for the reservoir rights-of-way here suggested were necessary because, although in each case some of the required land was in private ownership, both of the dam sites are on the public domain and some government land would be flooded by the construction of dams. The right to use land for the reservoirs and the right to erect dams could be granted only by the Secretary of the Interior.

The first steps that were taken in this matter could not be made public without endangering the success of a movement for Tuolumne River water. Under joint action of the board of public works and the mayor, James D. Phelan, the city engineer was authorized to include in the surveys on the Tuolumne River such right-of-way descriptions at Lake Eleanor and in Hetch Hetchy Valley as were requisite in making formal application for the reservoir sites.

It was found upon inquiry that there was no precedent for an application by a municipality for a right-of-way in a national forest reservation. The advice received in the matter was that it would be safer to let an individual make the application and to let rights acquired thereunder be subsequently assigned to the city. This procedure had the advantage, too, that it obviated the necessity for publishing the intent of the city to apply for rights that were apparently to be had for the asking. Interference with speculative interests was thereby in all probability avoided. Mayor Phelan was obviously the proper person to make the application, but he had to do it as a private citizen. Subsequently, he made a complete transfer to San Francisco of all rights that might be acquired under his application. What Mayor Phelan did in this matter is what was asked of him by the city engineer and by the members of the board of public works. It is no more and no less than would have been expected of any other mayor.

The surveys were so far advanced that in October, 1901, an application could be made for the two reservoir sites, and the necessary papers were filed in the Stockton land office. More

than a year elapsed before word was received from Washington that the application for both rights-of-way had been rejected on the ground that the law made it obligatory upon the Secretary of the Interior to preserve the natural wonders in national parks. The city was advised by the Secretary of the Interior that congressional action would be necessary to make the utilization of the two sites possible. The usual opportunity for requesting a review of the decision was, however, given to the city. A review was granted and the city, through its city attorney and its city engineer, presented its case to the Secretary of the Interior in March and April, 1903.

Until this time there had been no opposition manifest to the acquisition of water rights and reservoir sites by the city, although there had been no attempt to conceal the city's purpose after the application for reservoir rights-of-way had been filed.

In July, 1901, notices of claims to water had been posted in Tuolumne County and filed for record in the name of Mr. Phelan; in October, 1901, the filing in the land office was made and under date of July 28, 1902, the city engineer submitted a report on the Tuolumne River water supply project. In this report full explanation of the right-of-way applications was made. The matter had also received more or less attention by the newspapers.

At the hearing in Washington it developed, however, that the Spring Valley Water Works were represented by their manager in opposition to the city's application. Representation was made by him, not only that the city did not need to go to the Sierra Nevada for water, but that the water of the Tuolumne River could not be used by San Francisco without detriment to a large farming community which would ultimately require all the water of the river. At this hearing it also became apparent that the two irrigation districts had suddenly been awakened to a belief that the proposed water storage by San Francisco was a serious menace to the prosperity of the districts. So recent was this awakening that it was manifested by telegraphic communications from each of the two attorneys of the districts to the Secretary of the Interior.

It developed at this hearing, too, that the long time which had elapsed since the city filed its application had given private parties the opportunity to make surveys and file or offer for filing a rival application for the Lake Eleanor reservoir site. Mr. William Hammond Hall appeared as the representative of persons whom he would not name, and made the point that the

city had forfeited rights to priority in the matter of Lake Eleanor because it was disclosed by the cost estimate and general plans of the proposed works for utilization of Tuolumne River water that Lake Eleanor was not to be included as a part of the Tuolumne River project. The city needs both sites and no other conclusion is possible from a reading of the city engineer's reports than that the only question was the order in which they should be brought into use. The fact that a Lake Eleanor dam was not projected for immediate construction is no evidence that the same was eliminated from consideration as an essential ultimate requirement. The immediate construction of both reservoirs was not recommended for financial reasons.

The review of the Secretary of the Interior's decision did not lead to any modification thereof. The first conclusion that he could not grant the required privilege to San Francisco without legislation was confirmed. But the matter was not allowed to drop. The President and Congress were memorialized, and bills were introduced providing for a grant to San Francisco of the necessary lands at both reservoir sites.

The situation at this time is clearly set forth in the memorial adopted by the board of supervisors, on January 4, 1904, which is as follows:

"The board of supervisors of the city and county of San Francisco respectfully presents the following memorial to the President and Congress of the United States:

"*Whereas*, Under the provisions of the constitution of the state of California, 'the use of all water now appropriated, or that may hereafter be appropriated, for sale, rental or distribution, is . . . declared to be a public use, and subject to the regulation and control of the state, in the manner to be prescribed by law'; and the Civil Code of the state, in paragraphs 1410, 1411, 1413 and 1414, declares,—

"'The right to the use of running water flowing in a river or stream, or down a canyon or ravine, may be acquired by appropriation";

"'The appropriation must be for some useful or beneficial purpose, and when the appropriator or his successor in interest ceases to use it for such a purpose the right ceases';

"'The water appropriated may be turned into the channel of another stream and mingled with its water, and then reclaimed; but in reclaiming it, the water appropriated by another must not be diminished;'

"'As between appropriators, the one first in time is the first in right';

"*Whereas*, It has become manifest that the water supply of this city must sooner or later be increased by the addition of a

supply from the Sierra Nevada Mountains, and the securing of this supply should not be delayed;

"*Whereas*, The city and county of San Francisco proposes to appropriate for the use of its inhabitants, as authorized by law, water of the Tuolumne River, it having been found, as the result of the exhaustive investigations by the board of public works of San Francisco that this river is the best and most available source of supply to meet the immediate and future requirements of this large, important and rapidly growing city;

"*Whereas*, This appropriation of water is to be made without interference with vested rights, and this can be accomplished only by the storage of large quantities of the flood flow of the river and its tributaries;

"*Whereas*, The sites for the storage of the waste, storm or extra-seasonal waters of the Tuolumne River are located within a forest reservation generally referred to as a national park, and the Secretary of the Interior being authorized and empowered by the act of Congress, approved February 15, 1901, to permit the use of rights-of-way through the public lands, forest and other reservations for such reservoirs used for the supplying of water for domestic, public or any other beneficial uses to the extent of the ground occupied by such reservoirs, applications were duly made for two reservoir sites, one on the Tuolumne River, at the point known as Hetch Hetchy Valley, and one at Lake Eleanor;

"*Whereas*, These applications for reservoir rights-of-way were denied by the Secretary of the Interior, who points out that, as viewed by the Department of the Interior, 'the application is confronted by legal embarrassments which appear to be surmountable only by the exercise of the legislative power of the government';

"*Whereas*, The specific reason of the rejection of these applications is in part stated by the honorable Secretary of the Interior as follows: 'The act of October 1, 1890, makes it obligatory upon the Secretary of the Interior to preserve and retain the "natural curiosities and wonders" in the park in their "natural condition." This provision of the act which establishes the park remains in full force, not having been repealed or modified by the act under which this application is made nor by any other legislation.

"'It is contended that the appropriation of Lake Eleanor and Hetch Hetchy Valley for great reservoirs for the proposed storage of water would enhance rather than detract from their natural beauty, but this is not material in view of the law which commands the Secretary of the Interior to preserve and retain them in their natural condition if they are "natural curiosities."

"'There may be a difference of opinion as to what natural objects may be justly considered as being within the meaning of this provision of the law, but there can be no doubt about the duty of the Secretary of the Interior if, in his judgment, they are such natural curiosities or natural wonders so contemplated by the act';

" *Whereas*, Both of these sites have been recognized by the Department of the Interior as desirable and available for the storage of the flood flow of mountain streams, as demonstrated by the reports of the United States Geological Survey, in which these reservoir sites are repeatedly referred to. A plat of the Hetch Hetchy Valley was submitted to the Secretary of the Interior by the United States Geological Survey and its reservation from entry or settlement according to law was asked for under date of February 27, 1891. [See opening statement and page 36 of Part II of the Twelfth Annual Report of the United States Geological Survey.] A further report upon the availability of this reservoir site, with a study of the works necessary at the dam-site, are contained in the Twenty-first Annual Report of the United States Geological Survey, pages 450 to 465, in which, on page 459, it is stated: 'Another purpose which this dam and reservoir might be made to serve would be to furnish the city of San Francisco with an unfailing supply of pure water. Without entering into details, it will suffice to say that the dam and reservoir as proposed would insure a supply in the driest years of 250 gallons per diem per capita for 1 000 000 people.' Lake Eleanor and the segregation of its lands for reservoir purposes is referred to in Part II of the Eleventh Annual Report of the United States Geological Survey, page 157, on the plate between pages 160 and 161, and on page 167; also in the Thirteenth Annual Report, Part III, page 402;

" *Whereas*, It is not conceivable that the maintenance of a forest reservation with an area of about 1 500 square miles is to interfere to any material extent with the development of water for useful purposes, particularly when such utilization introduces into the park a new lake about 2 square miles in area and enlarges a second from less than one half to nearly two square miles, enhancing the natural beauties of the park instead of detracting from them;

" *Whereas*, Neither of the two sites in question is now accessible by wagon road, and will never be visited by any considerable number of persons except in the months, July, August and September, when the stage of water in the lakes will be high;

" *Whereas*, The use to which the water is to be put is the highest possible beneficial use;

" *Therefore*, this board memorializes the President and Congress of the United States to pass such laws as may be necessary to grant to the city and county of San Francisco the right to use the reservoir sites heretofore applied for."

In addition to this a direct appeal was made to the President for the city by Mr. Marsden Manson, now city engineer, and resulted in the obtaining of an opinion from the Attorney-General of the United States to the effect that the power to grant rights-of-way as applied for by San Francisco was vested in the Secretary of the Interior. The bills before Congress were not, therefore, pressed.

In the meanwhile Mr. James R. Garfield succeeded Mr. E. A. Hitchcock as Secretary of the Interior, and in the light of the Attorney-General's opinion a request was presented to him to have the matter reopened. This request was granted and after many conferences and long deliberations San Francisco has been granted the rights asked for, subject, however, to such control on the part of the United States government as will protect the prior rights of the irrigation districts.

In order that the situation may be clearly understood, a brief description of the works now in use and of the proposed Tuolumne River project is here given.

Water Works hitherto in Use. Sources Developed.

Practically the entire city is now supplied with water by the Spring Valley Water Company. The service of the Visitacion Valley Water Company, of the John Center Works which were of such great service in checking the southerly advance of the great fire in 1906, and of a few other minor concerns, is so small that it need not be further considered in this discussion.

It is noteworthy, however, that for various purposes water in large quantity is drawn from the bay and the ocean, thereby decreasing measurably the demand on the established service. Various concerns use salt water for condensing. The Olympic Salt Water Company supplies some water for this purpose and some for bathing, drawing its supply from the Pacific Ocean. The power stations of the United Railways are all supplied with salt water drawn from the bay for cooling purposes. The city is now about to construct a high-pressure fire protection system which will draw water from wells and from the bay.

For use in Golden Gate Park water is pumped from wells at two points: at a pumping station near H Street and Thirteenth Avenue for general use, and at a point near the ocean by a Dutch windmill for a supply to the chain of lakes and other uses. The Presidio draws water from wells at Mountain Lake.

The fact that a large amount of salt water and locally obtained water will always be used for various purposes; that the climatic conditions, particularly the cool weather and fogs of summer, keep down the water consumption, and the fact that restricted building areas will compel the crowding together of residences and will keep down the area of lawns and gardens — these facts all contribute to make the water requirement of San Francisco relatively small. It can probably, without undue restrictions upon the water consumer, be kept at about 80 gal. per inhabitant.

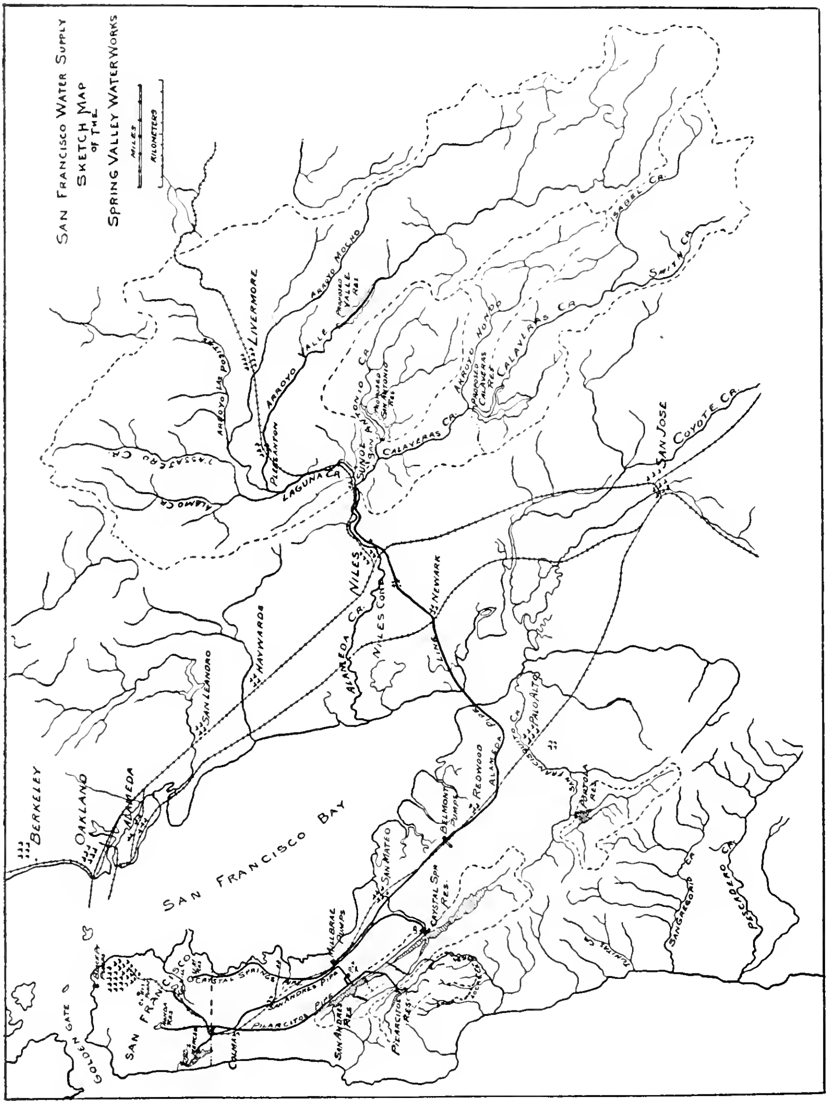
In the early days of San Francisco's history, water for drinking purposes and domestic use was peddled about the streets in water wagons. Fire protection was afforded by fire engines operated by hand and by cisterns which were filled with salt water pumped from the bay.

About 1858 Lobos Creek water was brought into the built-up portion of the city by the San Francisco City Water Works. The flume around Fort Point, at an elevation of about 20 ft. above the ocean, which was in service until 1895, will be remembered in this connection. This source of supply remained in use, therefore, nearly 40 years. Lobos Creek was not finally abandoned, however, as a possible source of water until the year 1901.

The construction of the City Water Company's works, which included a pumping station at Black Point and a reservoir on Russian Hill, was quickly followed by the organization of a rival company. The projector of this rival company was Geo. H. Ensign, who controlled certain water rights deemed to be adequate for the intended purpose. Among the sources that had been or that were being drawn upon was a spring located somewhere on the slopes of Clay Street Hill in a depression then known as Spring Valley. This explains the name adopted by the company. Under date of January 1, 1865, the San Francisco City Water Works sold out to the Spring Valley Water Works, and the latter corporation five years ago sold out to the Spring Valley Water Company.

As the city grew the nearest sources of water were one by one abandoned and new sources farther away from the center of population came into use. As early as 1863 to 1865 the Pilarcitos reservoir was constructed and added to the system. It came into use as a small reservoir formed by a low earth dam, which was submerged and went out of service when the present higher dam was completed in 1869. San Andres reservoir came into use in 1870, and the Upper Crystal Springs or Cañada de Raymundo reservoir, now a part of the Crystal Springs reservoir, about 1878. Merced Lake was added to the water works in 1877 and 1878. The explosion of a boiler wrecked the pumping station at this lake in 1885, and it remained out of use thereafter until 1891, when the present pumping station came into service. Alameda Creek water, the right to which had been acquired in 1875 by the purchase of the Alameda Water Company's properties, was first brought across the bay in 1888. The diversion was then at the Niles dam. Seven years later the point of

GRUNSKY. PLATE I.



diversion was changed to Suñol valley, and the filtration feature was added to this part of the water works system. The amount of water diverted from the creek was materially increased at that time. The construction of the Crystal Springs concrete dam on San Mateo Creek was commenced in 1886, and work on this structure was continued until 1892. Lobos Creek went out of use with the destruction by landslides of the flume around Fort Point in 1895. It was to be again added to the system in 1901, but yielding to the wishes of the city authorities the water company finally abandoned it as a source of supply in the same year.

Pilarcitos reservoir is fed by a creek of the same name which courses down the ocean slope of the Montara spur of the coast range. It is located about 12 miles south of the south boundary of San Francisco. The elevation of the water surface of a full reservoir is 682 ft. above San Francisco city base (this base is about 10 ft. above mean sea level). The reservoir is formed by an earth dam 90 ft. high and 730 ft. long on the crest. Its surface area when full is about 105 acres. The storage capacity of the reservoir is 940 000 000 gal.

Until destroyed by the earthquake of 1906, a wrought-iron pipe, 30 in. in diameter, brought the Pilarcitos water into San Francisco. Since that time the Pilarcitos water is allowed to flow into San Andres reservoir and reaches the city through the San Andres pipe. The watershed tributary to the Pilarcitos reservoir is 3.5 sq. miles, to which, by side hill flume, about 1.4 sq. miles more has been added.

San Andres reservoir is about two miles nearer to San Francisco than the Pilarcitos reservoir. It is located on the bay side of the mountains and at a lower altitude. Its elevation when full is 435.6 ft. above city base and the surface area of the reservoir is 475 acres. This reservoir lies on a small branch of San Mateo Creek and there is tributary to it, naturally, a watershed having an area of 4.1 sq. miles. To this there was added in 1897, by a tunnel known as the Davis Tunnel, an area of 0.9 sq. miles cut-off from San Mateo Creek. The Locks Creek line of flume and pipe, which was in service until about 1899, added run-off waters from 3.4 sq. miles of additional area. Thereafter for several years all of the Locks Creek line above Apanolio Creek was out of service. Now the New Locks Creek line is in the main an interceptor of Pilarcitos water below Pilarcitos dam, including wastage from Pilarcitos reservoir. The area at present made partially tributary to Lake Andres by this conduit includ-

ing 1.5 square miles of San Mateo Creek below the Davis tunnel, may be taken at about 3 sq. miles. The San Andres dam is an earth embankment, lying just on the edge of the fault line on which there was a horizontal movement of about 7 ft. at the time of the earthquake of 1906. The abutment of the dam is cut by the fault. The dam has remained intact and uninjured. The dam is 90 ft. high, and has a crest length of 990 ft. The San Andres reservoir when full holds 5 723 000 000 gal. of water. Waste water, when there is any, flows from this reservoir into the Crystal Springs reservoir. The water from this reservoir flows through a tunnel 2 820 ft. long into a measuring box, then into a screen house, where it is passed through cloth screens. It is thereupon carried in 28 849 ft. of 44-in. wrought iron pipe, 40 185 ft. of 30-in. pipe and 1 400 ft. of 37-in. pipe, the latter across a creek between Baden and Colma, to San Francisco, where delivery is made into the College Hill reservoir.

The Crystal Springs reservoir is the largest of the storage reservoirs on the peninsula. It lies about 4 to 8 miles further from San Francisco than the San Andres reservoir. It is formed by a dam across San Mateo Creek just below the point where the creek receives the waters of the Cañada de Raymundo from the south. The reservoir as it now exists is formed by a massive concrete dam. This was constructed in the years 1887 to 1892. The dam is to be raised 30 ft. at some time in the future. As it now stands it has a height of 146 ft. and the reservoir formed by it has a capacity of about 18 900 000-000 gal. The elevation of the top of the present structure is 280 ft. above city base.

Some years before this dam was constructed, as already stated, there had been constructed the Upper Crystal Springs or Cañada de Raymundo dam. This dam is of earth. On its crest, which is slightly higher than the crest of the Crystal Springs concrete dam, is a road. Upon the completion of this dam in 1878, and for seven years thereafter, the water stored by it was pumped into the San Andres system. But in 1885 the 44-in. Crystal Springs pipe line was completed and water then flowed by gravity from the Cañada de Raymundo reservoir to the University Mound reservoir in San Francisco. The earthquake of 1906 split the dam crosswise, one end of the structure being moved about 8 ft. with reference to the other. At the time of this earthquake, April 18, 1906, the water level on both sides of the dam was the same. There was, therefore, no flow of water through the structure and no damage from this

cause. The dam has been of no importance as a feature of the water works since the construction of the concrete dam.

The Crystal Springs concrete dam is about 600 ft. long on top. It is arched upstream. About 164 000 cu. yd. of concrete were required in its construction and in the construction of a deep cut-off wall across a low gap north of the hill against which the north end of the dam abuts. At the elevation of the present top of the dam the water surface area of the reservoir is about 1 300 acres. The area of the watershed tributary to the Crystal Springs reservoir, not including the area cut off by the Davis tunnel, is about 23.2 square miles. Of this area about 12 square miles were tributary to the Upper Crystal Springs reservoir. The conduit from the Crystal Springs reservoir to San Francisco is a 44-in. wrought-iron pipe. The route followed by this pipe is along the bay shore. It crosses a long stretch of swampy ground near Baden and lies upon hilly and otherwise difficult ground at Sierra Point. One spur of the hills is here pierced by a tunnel 300 ft. long. After crossing Visitacion valley the conduit is again in tunnel 2 145 ft. long. It discharges into University Mound reservoir. The total length of this conduit is 87 066 ft.

Among the works on the peninsula south of San Francisco that are productive of water is the Locks Creek line. Originally this aqueduct included a long conduit skirting the ocean slope of the mountains into which water from a number of small creeks was admitted.

The upper end of the conduit was at Locks Creek. About 1897 the upper part of the works down to Apanolio Creek and in 1901 another section below this creek, went out of service. Since 1901 the lower part of this line as reconstructed has alone been in use. At the head of these works as now in service on Pilarcitos Creek, about a mile below the Pilarcitos reservoir, is a stone dam about 35 ft. high. This dam diverts the flow of Pilarcitos Creek into a flume. To the natural flow of the creek there is here added some water intercepted by a hillside flume, which discharges into the basin above the stone dam. The overflow or waste water from the Pilarcitos reservoir reaches the stone dam and opportunity is thus afforded for turning it into San Andres reservoir. The flume from the stone dam carries the water about three quarters of a mile to a tunnel 3 200 ft. long, which pierces the ridge between the Pilarcitos and the San Mateo drainages. The water, after passing through this tunnel, is carried in a flume about 2 miles to the point where

San Mateo Creek is crossed from west to east. A second tunnel carries the water through the ridge between San Mateo and San Andres valleys. This tunnel is about 3 530 ft. long. At the westerly or San Mateo end of this tunnel the Locks Creek flume is joined by a flume from the north which adds San Mateo Creek water that has been diverted by a concrete dam from that creek. About 1.5 sq. miles of the watershed of San Mateo Creek lying next below the area for which Davis tunnel is an outlet are thus made partially tributary to San Andres reservoir.

The water consumption from the Peninsula reservoir system has been about 18 000 000 gal. per day. This is in round numbers at the rate of 530 000 gal. per day per sq. mile of tributary watershed. The amount of water wasted has been relatively very small, due to the large capacity of the reservoirs when compared with watershed areas. In years of ordinary rainfall Pilarcitos reservoir is the only one which is likely to be filled to overflowing, but as explained, nearly all of the surplus is conserved by the interceptingworks which carry it into San Andres reservoir. The overflow from the San Andres reservoir goes into the Crystal Springs reservoir, and the Crystal Springs reservoir has been full to overflowing only twice in its history, in 1889 and in 1895. The above-noted water production of 530 000 gal. per day per sq. mile may, therefore, be accepted as very nearly the normal for this region, in which 43 in. per year is the normal fall of rain.

When the amount of storage on the peninsula is compared with the amount of storage usually provided to equalize the flow of streams on the Atlantic coast, it seems large, but the need for the relatively large reservoir capacity results from the peculiarity of the climate. The rainfall records show that there may be two or even three years in succession in each of which rainfall is so light that there is very little run-off. To tide over such periods that are unproductive of water a large supply of water must be held over from the preceding seasons of more copious rainfall. Col. G. H. Mendell, who gave the subject much thought, reached the conclusion, as laid down in his report of 1877 on the San Francisco water supply, that so long as the city relied upon the coast range sources of supply the storage capacity of the reservoirs should be a 900 days' supply.

When a reservoir is located on a stream whose flow every year is adequate to fill it, this rule is, of course, without force. But even after some of the larger rivers of the state are made tributary to the established works, the storage of water in large quantity near the city is essential to make the service reliable.

The matter of securing other sites has been investigated and one at Belmont was selected for use as a feature of the Tuolumne River project. It goes without saying that the use of this site should only then be contemplated if the city fails to come to an understanding with the Spring Valley Water Company. The water company in extending its works from time to time naturally occupied the best and most available sites. The storage reservoirs now in use, particularly with the Crystal Springs dam raised to the full proposed height, will be adequate to meet every requirement.

The peninsula sources of water, which as described flow by gravity into San Francisco, are supplemented by Lake Merced. This lake lies close to the Pacific Ocean, just north of the southerly line of San Francisco. The elevation of its water surface at all stages is above sea level. The water in the lake, for the most part, is the outflow from the sand deposits that lie within the lake watershed. The surface run-off, which formerly reached the lake, is now intercepted and turned through a tunnel, past the lake into the ocean.

The lake has two arms that were originally connected by a narrow strip of water. They are now separated from each other by an earth dam. Structures have been built for the interconnection of the two lakes so that one pumping station may draw upon the water of both lakes. The surface area of Lake Merced is about 330 acres. When full its available contents are about 2 000 000 000 gal. The lake is not attractive as a source of water for domestic use, but for many years its water has been used mixed with the waters from Pilarcitos and San Andres reservoirs. It is protected against pollution by a system of works which intercept and deliver into the ocean the surface run-off from the inhabited portions of its watershed. These works include a brick conduit and tunnel from near the head of the south arm of the lake to the Pacific Ocean and a long flume from Ocean View; also a conduit for the Ocean View sewage. The large capacity and nearness of Lake Merced to the place of use will always make it a valuable addition to a municipal supply, even though no water be drawn from it except in case of emergency. When a Sierra Nevada water is added to the city water supply system the surplus should be allowed to flow into the Crystal Springs reservoir and into Lake Merced, thereby keeping these reservoirs as nearly full as practicable, and incidentally improving the quality of the stored water in each.

The value of Lake Merced as an emergency supply, if water

production may be considered, is not fully measured by its storage capacity, because the experience of the past indicates that it may be relied upon for a continuous supply of water amounting to about 3 000 000 gal. per day. The pumping station at Lake Merced has a capacity of about 7 000 000 gal. per day. It delivers water into the conduit that brings the water of Pilarcitos reservoir into the city.

So long as Lake Merced remains in use as a source of water, the human activities in the tributary watershed should be kept down as much as possible. Notwithstanding the works for the interception of surface drainage from the south and sewage from the east, there is a menace due to such activities that should be kept at a minimum. There is good reason, therefore, for preserving the lands near Merced Lake, if the city ever acquires them, as a park, whereby population can be excluded from the greater portion of the drainage basin and good police regulations can be enforced.

In 1887 it became apparent that the peninsula sources of water as then in use were inadequate to meet the demand for water. The immediate extension of the works to the easterly side of the bay of San Francisco was, therefore, determined upon. Rights to water in Alameda Creek had, as already stated, been secured, as early as 1875, by purchase of properties of the Alameda Water Company. This purchase included, besides these water rights, a part of a reservoir site on Calaveras Creek.

The Alameda Creek works, as commenced in 1887 and completed in 1890, were for the diversion of the natural flow of Alameda Creek at a dam about 2½ miles above Niles, and the delivery of this water by gravity flow through a long wrought-iron pipe conduit into a small receiving reservoir at Belmont, from which it is pumped through a pipe to Burlingame into the main from Crystal Springs reservoir.

The capacity of the works as thus constructed was about 7 000 000 gal. per day. They remained in service at this capacity for about 10 years, then the system was changed, by the addition of works higher up on Alameda Creek, and as a result of the change, which included a greater head to force water through the conduit to Belmont, the capacity of the Alameda Creek system was raised to about 10 000 000 gal. per day, at which it remained until further increased in 1903.

As now in use, the works include filtration in a large natural gravel deposit of the Suñol Valley. Water of Laguna (Alameda) Creek and of Calaveras Creek is brought within reach of this

gravel bed by a system of ditches. It sinks from these and from the natural channels into the gravel beds. It is intercepted in these gravel beds by a timber filter gallery placed in the bottom of a deep open cut, which is about one-half mile long and terminates in a concrete sub-surface aqueduct into which the water is also directly admitted through many small openings in its side walls. The concrete aqueduct is about 3 000 ft. long. It has a side feeder intended to more completely intercept the water coming down the creek channel. At its lower end it is connected with a gallery or conduit leading across Alameda Creek, from right bank to left bank, within the concrete diverting dam which has been placed across the Alameda Creek at the lower end of the Suñol Valley. This diverting dam is primarily intended to check any outflow from the gravel beds of Suñol Valley at less elevation than the crest height of the dam. The gravels are thus made to serve in some measure as a reservoir. The dam may also be used, if conditions require it, to divert the creek water directly into the conduit which takes it from this point down the Niles Cañon to the head of the pipe line.

The water from the Suñol Valley gravels, after crossing Alameda Creek as described, is carried by tunnel and flume along and in the mountain slopes on the south side of the cañon for a distance of 5 miles to a screen house, at elevation 180 ft., and there enters the pipe which conveys it to Belmont. About 3 miles of the 5 are in tunnel. The total length of the Alameda Creek pipe line from the screen house near Niles to the junction with the Crystal Springs main is about 29 miles. The pipe to Belmont is 36 in. in diameter, except where a slough and the Bay of San Francisco are crossed near and at Dumbarton Point. At each of these two places the water was carried in two 16-in. submerged pipes until 1902, when two submerged 22-in. steel pipes were added. The pressure main from the Belmont pumps to Burlingame is 36 in. in diameter. From Burlingame to Millbrae the 44-in. Crystal Springs main was paralleled in 1903 by a 54-in. main ni which the Alameda Creek water can be carried apart from the Crystal Springs water to the Millbrae pumping station and by the pumps there located can be forced into the San Andres main. The water supply from Alameda Creek is reinforced by the flow from 22 artesian wells in Livermore Valley near Pleasanton. A line of wells has been bored across the lower end of the Livermore Valley to the gravel beds, from which they bring to the surface about 7 000 000 gal. of water per day. This water is discharged into the creek and flows therein to the head

of a ditch which leads it into the Suñol Valley along or near the upper edge of the Suñol gravel deposits. The yield of the Alameda Creek system is now about 15 000 000 gal. per day.

There are a number of pumping stations connected with the water works. Some of these will be referred to in presenting salient features of the distributing system; others deserve special notice because of their peculiar function in transferring water from the lower to the higher levels.

The function of the Belmont pumps, as already explained, is to deliver Alameda Creek water either into the Crystal Springs main or to feed the Millbrae pumps for delivery into the San Andres main. The pumps at the Belmont station first went into service in 1888. New pumps were added in 1903. The present aggregate capacity of the pumps at this station is about 23 000 000 gal. per day.

The Millbrae pumps were installed with a capacity of about 16 000 000 gal. per day to force some of the water arriving in the Crystal Springs main into the higher San Andres main. Since the completion of the pressure main from Belmont to this station the Millbrae pumps serve also to send Alameda Creek water into the San Andres main.

The Pilarcitos pumps are located at the lower end of the outlet tunnel of the San Andres reservoir. The function of these pumps is to deliver San Andres water into the Pilarcitos main. Their capacity is about 4 000 000 gal. per day.

At Ocean View is an emergency pump of small capacity which serves the same purpose but has been but little used, if at all.

At the Crystal Springs dam is a pumping station which may be used to lift Crystal Springs water into a flume which carries it northerly into San Andres Lake. The capacity of the pumps here located is about 12 000 000 gal. per day.

The pumps at Lake Merced are connected with the San Andres and Pilarcitos mains in such a way that without loss of pressure the water from the San Andres main can be pumped into the Pilarcitos main. By suitable interconnection of pipes the two pumps at Lake Merced can be made to draw simultaneously either upon the lake or upon the San Andres main, or one pump can be fed from the main while the other draws its supply from the lake. The lake water, as already explained, is pumped into the Pilarcitos main and flows into Lake Honda receiving reservoir. The capacity of the Lake Merced pumps is about 7 000 000 gal. per day.

Before passing on to a description of the city distributing system it should be stated that all of the water, before delivery into the city receiving reservoirs, is screened. The screen house, near Niles on the Alameda conduit, is equipped only with wire mesh screens to remove occasional leaves and the like blown into the flume by the wind. The water which reaches University Mound reservoir all passes through a screen house there located. At this screen house, as at those on the San Andres line and at Lake Honda, the water is made to pass through ingeniously arranged screens of cheesecloth. After a set of screens has been in service about 1½ hours, the water is turned off and the screens are cleaned with a jet of water. Particles of vegetable matter, principally algæ, are removed from the water in this way. The screen house on the San Andres pipe line is located at the lower or easterly end of the outlet tunnel of San Andres reservoir. At Lake Honda is a screen house for the treatment of the water arriving in the Pilarcitos main.

Distribution.

San Francisco is a city of hills. The distribution of water under adequate pressure to all parts of the city is not, therefore, a simple matter. Some of the characteristic features of the distributing system as now in use are here briefly stated.

University Mound reservoir, capacity about 30 000 000 gal., located in the southeasterly portion of the city, at an elevation about 165 ft., receives the water from Crystal Springs reservoir with any added supply from Alameda Creek. The main conduit from this reservoir crosses Islais Creek on a trestle and supplies the low down-town section of San Francisco. The pumps at Black Point, which have a capacity of 5 500 000 gal. per day, draw upon this low-pressure system and serve the high-lying hilltops in the northern part of the city. Water is delivered by these pumps into the upper reservoir on Russian Hill and into the steel tanks on Clay Street hill and out on Presidio Heights. The Francisco Street reservoir, at elevation 140 ft., is at the end of a large main of the low-level system and serves admirably as a recipient of water during the night and a pressure equalizer during the day.

College Hill reservoir, in the south central part of San Francisco, receives the waters arriving in the San Andres main. The capacity of this reservoir is about 15 000 000 gal. Its elevation is 255 ft. It supplies a zone of very irregular outline next above the low-level area.

Lake Honda, located south of Golden Gate Park near the Almshouse tract, receives the waters of the Pilarcitos main. It has a capacity of 33 000 000 gal. Its elevation of 365 ft. gives it command of a region next above that served from the College Hill reservoir. The greater portion of the Western Addition is served from this receiving reservoir.

The highest district in the city now served with water is supplied through the Clarendon Heights pumps located at Seventeenth and Noe streets. The pumps have a capacity of 5 000 000 gal. per day. They can draw either upon the University Mound or the College Hill system. The pumped water is delivered into the Clarendon Heights tank, which is located on a spur of the Twin Peaks at an elevation of about 600 ft.

The gradual growth of San Francisco, and the need of keeping outlying districts, though sometimes sparsely populated, supplied with water, has led to the retention in use of much pipe of smaller diameter in many streets than would now be laid therein. The network of pipes now in use is not, therefore, fully up to the standard that would be prescribed for an entirely new system, particularly so long as water for extinguishing fires is supplied through the same mains which distribute water for other uses. Some idea of this fact results from a comparison of the pipes that would be required in a new distributing system (as planned in 1902) with the pipes now in use.

Pipes in Distributing System, 1902.

Diameter of Pipe, Inches.	Water Pipes of the Spring Valley System.		Water Pipes of the Proposed Tuolumne System (including Specials).	
	Wrought Iron, Feet.	Cast Iron, Feet.	Wrought Iron, Feet.	Cast Iron, Feet.
Specials		16 000		
3		130 809		
4		344 321		81 700
6		570 983		170 230
8		621 900		1 868 910
10		9 912		312 190
12		226 278		785 080
15	850			
16		121 154		752 780
20		21 840		90 960
22	25 481	23 488		52 740
24		20 820		395 540
30	12 669	4 494		227 830
33	2 510			
36			12 650	
37½	12 254			
44	7 213			
48			47 940	

Before the fire in 1906 there were in San Francisco about 50 000 connections with the Spring Valley Water Company's pipes. This number was reduced to about 30,000 after the fire. It is now in the neighborhood of 40,000.

Aeration and Measures to Prevent Pollution.

The water delivered to San Francisco comes in large part from storage reservoirs, in which its appearance and quality are without doubt improved. But as these reservoirs are fed by streams that are turbid during their freshet stages, and as they are located at low altitudes, exposed to the hot summer sun, it has not been possible to keep them entirely free from minute algæ and other vegetable growth. The screening process to which the water is subjected, as explained, removes much of this objectionable matter and the quality of the water is further improved by aëration, which is effected by discharging it upon an elevated platform from which it drips in successive stages to lower platforms. The water of the Pilarcitos pipe line and that pumped from Lake Merced are thus aërated on Daly's hill near the point where the Pilarcitos line crosses the south boundary of the city; the San Andres water is aërated just before being delivered into College Hill reservoir.

The main reliance for preserving the wholesomeness of the water supply is placed by the water company upon the protection of the watersheds against pollution. Over 2 700 acres, 4.4 sq. miles, or more than one half of the area tributary to Lake Merced, is thus owned. About 28 of the 36 square miles of watershed in whole or in part tributary to the Peninsula reservoirs are owned by the water company. On Laguna, Calaveras, San Antonio, Valle and Hondo Creek of the Alameda Creek system, the area owned is close upon 25 000 acres. On those portions of the watersheds where sources of pollution were most to be feared, the police control and the restriction of human activities have been made easy and effective by this policy of land ownership. The Coast Range sources of supply now utilized, or noted as within reach of the Spring Valley Water Company, are, nevertheless, not ideal sources of water for domestic use. The collecting ground is not of the high snowcapped mountain type, but is of the low soil-covered mountain and foothill character. Much of it is brush covered. Animal life and a certain amount of human activity in the watersheds, the natural turbidity of most of the water and the presence in it at times of more or less organic matter all point to filtration as a proper treatment

for the improvement of the water. Some of it, in fact, may be considered as already receiving this treatment. The water that issues from the Pleasanton wells has passed long distances through gravel deposits and that of Suñol Valley as collected in the filter galleries issues clear and inviting.

Undeveloped Sources within Control of Spring Valley Company.

Among the properties owned by the Spring Valley Water Company which have not been developed there may be noted:

Calaveras Valley on Calaveras Creek.—This is a reservoir site to which there are directly tributary about 100 sq. miles of the region round about and to the north of Mt. Hamilton. To this area about 40 sq. miles more can be added by diverting Hondo Creek waters into the Calaveras Valley. The rainfall on the watersheds that are or can be made tributary to the Calaveras Valley is only about two thirds of the rainfall near the Peninsula reservoirs. The water production will, therefore, be less. It will in a year of normal rainfall probably be about 225 000 gal. per sq. mile per day. The total water supply that can be hoped for from this source is not, however, to be deduced directly from this unit quantity and the drainage area. It will depend in a measure upon the extent to which the Hondo Creek waters can be intercepted, and in a large measure upon the amount of water that will reach the reservoir site in wet years in excess of storage capacity. The dam site for the Calaveras Valley reservoir has been thoroughly explored by the engineers of the Spring Valley Water Company and so far as has been disclosed by them the results of the examination are satisfactory. A dam with a crest 187 ft. above the natural surface of the ground would, according to estimates made by Mr. T. R. Scowden, who investigated this matter for San Francisco in 1874, create a storage capacity of about 30 000 000 000 gal. The run-off from the watersheds directly and indirectly tributary to the Calaveras reservoir will, in seasons with the maximum fall of rain, be more than twice this amount.

San Antonio Creek.—San Antonio Creek is a tributary of Calaveras Creek. On this creek a short distance above the point where it enters the Suñol Valley is a reservoir site to which about 40 sq. miles of the low mountain region northeasterly from Mt. Hamilton are tributary. On this watershed the rainfall is somewhat less than on that of the Calaveras reservoir. The amount of water which flows through the reservoir site

in a year in which the rainfall is normal is equivalent to an average flow of about 5 000 000 gal. per day.

It is to be noted that both the dam at the Calaveras site and the dam at the San Antonio site will hold back water that now flows to the Suñol gravels. There is, therefore, a certain interrelation between the amount of water produced by the intercepting works in the Suñol Valley and the water impounded in the reservoirs. This is also true of the proposed water development by storage on the Arroyo Valle. This last-named creek enters the Livermore Valley from the south and much of its flow sinks before reaching Pleasanton. It is a feeder and perhaps the principal feeder of the artesian strata from which the Pleasanton wells obtain their supply.

On the Arroyo Valle the Spring Valley Water Company has secured a foothold. It owns or controls a reservoir site of moderate capacity. The watershed tributary to this reservoir site is about 130 sq. miles, and the normal rain upon this drainage basin may preliminarily be taken at about 24 in. per year. The amount of water which flows through the reservoir site in a year with normal rain should be about 18 700 000 gal. of water per day.

On the Niles cone, too, the water company has acquired lands. The Niles cone is a flat gravel deposit which spreads out, fanshaped, from the mouth of Niles Cañon southwesterly across the valley region east of San Francisco Bay. It is permeated by the waters of Alameda Creek. These waters are within reach of pumps, and their development may in time be justified. As the total area of the watershed tributary to the Niles Cañon is about 600 sq. miles, and the three reservoirs above enumerated intercept (though only in part) the run-off waters from 310 sq. miles, there will always be some water, at least in wet years, from the other 290 sq. miles, together with the wastage from the reservoirs, to replenish the water of the gravel beds in Livermore Valley, in the Suñol Valley and in the Niles cone.

It will be readily understood that the lack of data, particularly in so far as they relate to the dimensions of structures by means of which water is to be stored, capacities of reservoirs to be created and capacities of conduits for the utilization of the water or its transfer to other reservoirs, as well as more or less uncertainty relating to rainfall and run-off, would render useless any attempt to now make a final estimate of the water production of the various sub-elements of the Alameda Creek

system. The daily watershed production above noted for the several reservoirs in years of normal climatic conditions on tributaries of Alameda Creek are only a first indication of possibilities. They cannot be fully realized. Even in the case of the Calaveras reservoir, which has a very large capacity, the inflow from the tributary watershed (including Hondo Creek) may in a single year of maximum rainfall be enough, as already stated, to fill the reservoir twice. Some water being assumed in storage at the beginning of such a season, there will then be large wastage, of which perhaps only a small portion may become available by infiltration into the Suñol gravels and the Niles cone. The proportional wastage in occasional years on the San Antonio and on the Arroyo Valle will be still greater, because the storage is there relatively smaller.

However, to give some idea of the total possible water production on Alameda Creek in its entirety, it may be stated that the mean run-off indicated by drainage area and rainfall is estimated at about 90 000 000 gal. per day. If this amount of water, or whatever the exact figure for the Niles Cañon flow may be, were intercepted by adequate devices above Niles Cañon, there would be no water for the Niles cone. This total, therefore, represents the extreme water production of the Alameda Creek watershed, including all local water consumption for whatever purpose and the waste, if any, by surface or subsurface routes to the bay.

San Francisquito Creek is frequently referred to as available for increasing the water production on the peninsula by about 7 000 000 gal. per day. This is probably an overestimate. It is understood that the Leland Stanford, Jr., University has a right to the first 3 000 000 gal. per day. As the run-off, estimated from the rainfall and the watershed of 15 sq. miles, will average only about 6 500 000 gal., this source should not be credited with a possible production of more than 3 000 000 to 3 500 000 gal. per day. On this creek there has already been constructed at Searsville a concrete dam 90 ft. high, which is to be raised to a greater height at some future time.

Of the various ocean slope creeks on the peninsula only one, as explained, Pilarcitos Creek, is at present made tributary to the established works. But it is generally admitted that if it were necessary to do so, though at relatively large expense, some additional ocean slope water could be intercepted and turned through a tunnel to the bay side of the mountains and ultimately into the Crystal Springs reservoir. To accomplish

this a long conduit of large capacity would be requisite. The ocean slope creeks afford but scant opportunity for storage at elevations that would permit water to flow from the collecting reservoirs into the Crystal Springs reservoir. The interception of storm waters would, therefore, be restricted to the short periods in winter when the creeks are high. During the rest of the year the natural flow of the streams is small, consequently only a small percentage of the annual output of the stream is then available for interception. A special study of the features of a project for the utilization of the ocean slope waters would have to be made before a close estimate of the probable ultimate yield of these sources could be made. But some idea of possibilities may be gained from the following: It is claimed that about 65 sq. miles of ocean slope drainages could be made tributary to an intercepting conduit with its head at Pescadero Creek. The run-off from this area, on which normal rainfall is about 40 in. per year, should average about 37 000 000 gal. per day, of which, depending upon the character and magnitude of the intercepting works, more or less would flow through the conduit. It is not at all improbable that about one half of this water can be made available, perhaps 20 000 000 gal. per day.

It now becomes possible to combine the foregoing figures relating to additional water development from sources that are near at hand and that are in whole or in part controlled by the Spring Valley Water Company. But to do this certain arbitrary assumptions must be made and these must be understood to be subject to modification as more data relating to storage possibilities, conduit capacities, rainfall and run-off become available. Thus it seems reasonable to expect that the Calaveras reservoir will make available about 25 000 000 gal. per day of the 35 000 000 that should flow through or past the reservoir in Calaveras and Hondo creeks. San Antonio reservoir may bring within reach 4 000 000 out of an average of about 6 000 000 gal. per pay, and on the Arroyo Valle about 10 000 000 gal. should represent the average amount intercepted.

The total run-off from the Alameda Creek watershed has already been noted at about 90 000 000 gal. per day. If the above amounts are realized on the tributaries named there will still be an average flow of about 51 000 000 gal. per day to feed the Pleasanton wells, the Suñol gravels and the Niles cone. As this water will come down the creeks mainly in wet winters when the creeks flash up quickly, a considerable portion thereof will

in all probability flow on to the bay and be lost. Some of it will be required for local use in Livermore Valley and elsewhere. It does not, therefore, seem safe to assume as a possibility that more than one half of the amount named, or about 25 500 000 gal. per day, can be intercepted by the Pleasanton wells, in the Suñol gravels and on the Niles cone, for delivery in San Francisco.

The water production of Spring Valley Water Company sources as developed and at ultimate capacity may, therefore, be tentatively stated as follows:

Sources.	Developed Supply. Gallons per Day.	Ultimate Supply. (Approx.). Gallons per Day.
Peninsula Reservoirs:		
Pilarcitos		
San Andres		
Crystal Springs	18 000 000	18 000 000
Lake Merced	3 000 000	3 000 000
San Francisquito Creek		3 500 000
Pescadero, and other ocean slope creeks		20 000 000
Alameda Creek:		
Calaveras Reservoir		25 000 000
San Antonio Reservoir		4 000 000
Arroyo Valle Reservoir		10 000 000
Pleasanton wells, Suñol gravels, Niles cone	15 000 000	25 500 000
Total	36 000 000	109 000 000

The foregoing statement in relation to the possible extension of the water works to other Coast Range sources of water is made to show that the possible expansion of the Spring Valley Water Company's system is not inconsiderable. It may also be noted that arrangements could be made to draw, in case of emergency, upon the great artesian water supply known to be within reach at the southerly end of San Francisco bay. A line of wells near Alviso would be a desirable addition to any water works system, but a draft upon such wells would, if long continued, have more or less effect upon the yield of the other wells in the Santa Clara Valley, and this source should not, therefore, be looked upon as available for large quantities of water except in cases of emergency and for short time periods only.

If the city were the owner of the water works under the circumstances, as above explained, attending their possible expansion, it would seem that the first step to take would be to supplement the developed supply by adding a large amount of

Sierra Nevada water. When this is accomplished the doubtful or least desirable sources now in use, such as Lake Merced, should, at least temporarily, go out of use. A time will then come when the works bringing to the city the mountain water will be taxed to their capacities. These works can then be added to and capacity increased until the limit of increase, indicated by the productiveness of the source, has been reached. This will be at a remote day, but when it comes recourse may still be had to the various additional nearby sources of water.

Supplemented by pure mountain water, the yield of the present sources of supply would be improved in quality. The peninsula reservoirs would be kept full of water or nearly so, and the Alameda gravels and Lake Merced would be called upon for water only when an emergency made this necessary.

The Tuolumne River Projected Development.

Although required, as city engineer, to plan water works with the Tuolumne River as the sole source of supply, the writer in his report on this project, and at other times, has pointed out that the needs of San Francisco would be best served by using the Tuolumne River sources in combination with the established water works system. No attempt has ever been made by him to belittle those advantages of the Spring Valley Water Works that are easily recognized in the nearness of its sources of supply to the place of use; in the reliability of the service rendered, due largely to the close proximity of some of its sources of supply to San Francisco and to works for safeguarding the service; in the large capacity of the storage reservoirs, which are close at hand, and in the fact that the service is an established one.

But the time is now at hand when a large addition to the water brought into San Francisco must be made, when it must be determined whether this addition shall be made by the Spring Valley Water Company or by the city; whether, in short, the water works that supply water to San Francisco are to be municipally owned or whether the established company should be allowed, as in the past, to expand its system by adding to it more water from Coast Range sources.

The writer's view that water consumption in San Fran cisco can be kept down to about 80. gal. per inhabitant is not shared by other engineers. Mr. Schussler, Mr. Stearns, Mr. Schuyler and others are of the opinion that the water consumption will increase much more rapidly than proportionally to population. They base their conclusions on the experience of

other large cities, notably of cities in the United States. Reasons for not accepting their conclusions have already been set forth. Be this as it may, the fact remains that San Francisco is a rapidly growing community, for which various forecasts relating to future population have been made, and that the growing city will demand more water from year to year.

The writer's figures relating to future population, as published in official reports, would probably have turned out to be underestimates if the city had not received the great setback resulting from the fire of 1906. They are given in the following table without correction for the loss of population in 1906, together with the estimates made by Mr. Schussler. It now seems probable that in ten to fifty years the actual population, unless increased suddenly by the addition of new territory, will lie somewhere between the figures noted in the table.

POPULATION AND WATER CONSUMPTION FORECASTS.

	Population.		Water Required, Gallons per Day.	
	Grunsky.	Schussler.	Grunsky.	Schussler.
1910.......	415 000	500 000	33 100 000	40 000 000
1920.......	490 000	650 000	39 200 000	55 000 000
1930.......	570 000	800 000	45 600 000	72 000 000
1940.......	650 000	950 000	52 000 000	90 000 000
1950.......	735 000	1 100 000	58 800 000	110 000 000

(TUOLUMNE) QUANTITY.

The quality of the water at the selected reservoir sites on Tuolumne River was investigated with satisfactory result. The question next to be answered related to the quantity that could be made available. On this point the writer, in his official reports, has been conservative. This question was treated throughout from the point of view that the Tuolumne River would be made the sole source of supply. The water production in a year of minimum rainfall was, therefore, used as a basis for the discussion of quantity that could be delivered, while the increase that would result from holding water over from one year to another in special storage reservoirs was not taken into account. Neither was any full discussion attempted of the amount of water development that would be possible by increasing storage at the selected sites by building higher dams. It was enough for the purpose of the reports on this subject to show that a development of water in large quantity was possible and that after the

needs of prior users on the stream were supplied there would be enough left to warrant the construction of the water works.

In the writer's official report on the Tuolumne River project it was shown that Lake Eleanor reservoir, if given a useful capacity of 12 000 000 000 gal., would be nearly twice filled in years of normal rainfall, and in years of minimum rainfall about three fourths by the run-off from the area directly tributary to the lake, and that the addition of other waters by interception, notably Cherry Creek, would bring to the reservoir in any year more water than required to fill the empty reservoir. Likewise it was shown that no year is to be expected in which the water flowing through Hetch Hetchy Valley will not be 20 to 25 per cent. greater than the proposed storage capacity of the reservoir.

The areas of the watersheds which are tributary to Hetch Hetchy Valley and to Lake Eleanor have been estimated at 452 and at 84 square miles respectively. The drainage basin of the Tuolumne River at La Grange, where the diverting dam of Turlock and Modesto irrigation districts is located, is 1 501 sq. miles. It follows, therefore, that there will be left in the river much of its natural flow entirely undisturbed by the works proposed for San Francisco.

To make a satisfactory estimate of the quantity of water that can be developed on the Tuolumne River for use in San Francisco more data are required than are now available. It is necessary in this case to know not only how much water per annum reaches the reservoir sites and the capacities of the reservoirs and conduits, but also to know the demands that will be made upon the river by other users of its waters. It is known that the river in the winter and spring months has a large flow, occasionally sending into San Joaquin Valley in 4 or 5 days as much water as would fill the proposed storage reservoirs. The retention of such storm waters in mountain reservoirs would admittedly be beneficial to all persons located on the river or using any of its waters. During the high stages of the river natural flow would supply all demands and there would be excess for storage. It is probable that the reservoirs would be drawn upon not more than 8 months in any year. Their proposed capacity, therefore, enables a first approximation to be made of the amount of water to be expected from this source. Estimated on this basis at least 170 000 000 gal. per day should be obtainable.

That this is a conservative estimate and will be materially

increased when more precise information is available appears from the following considerations:

The assumed minimum annual rainfall on the tributary watersheds will fill the reservoirs. This minimum is 18 in. per annum. It is in all probability too low, and if too low much more water will be available for storage than has been assumed, and larger reservoirs would be justified to equalize the river's flow.

No supplemental storage to equalize the flow, as between years of copious rain and years of light rainfall, has been assumed. Such additional storage is possible in the Hetch Hetchy Valley by constructing a higher dam and is possible in other sites of the Tuolumne basin. It is also obtainable near San Francisco, particularly if the Tuolumne project is made supplemental to the Spring Valley system.

The determination of the run-off in a year of light rainfall is, in other words, only a first safe approximation of the amount of water to be expected, and it is in this sense that the above estimate should be accepted.

(Tuolumne) Storage-Basins and Conduits.

The works by means of which it was proposed by the writer to make Tuolumne River water available in San Francisco may be briefly described as follows:

The granite gorge at the lower end of the Hetch Hetchy Valley is to be closed by a masonry dam rising to a height of 150 ft. above the valley floor. The gorge at the surface of the river has a width of 136 ft. The crest length of the dam, 150 ft. high, would be 400 ft. The dam would be arched upstream and surplus water would flow over its crest. Above the dam would be a bridge. The surface area of the reservoir would be about 1 180 acres. Its storage capacity would be 33 000 000-000 gal.

The additional storage at Lake Eleanor is to be secured whenever conditions make it desirable to regulate the flow of Tuolumne River still further than would be possible by a dam at Hetch Hetchy Valley alone. The Lake Eleanor dam would be located about 1¼ miles below the lake on a solid rock ledge. It would be about 75 ft. high, slightly arched upstream, and would have a length of 1 300 ft. The total amount of water impounded by it would be about 13 000 000 000 gal., of which about 12 000 000 000 gal. could be made available.

When still further storage is needed the first step to secure

it will be to raise the Hetch Hetchy dam. An added height of 50 ft. would about double the storage in Hetch Hetchy Valley. The higher dam would be quite feasible.

Except at times when the reservoirs are full and water is wasted over the tops of the dams, the outflow from the reservoirs would be under control. The outflow from the Hetch Hetchy reservoir would flow in the deep gorge of Tuolumne River about 16 miles from the point where it is discharged through the reservoir outlet works to a diversion point at or a short distance below the mouth of Jawbone Creek. A point about one mile below Jawbone Creek has been tentatively selected as the diversion point. Water from Lake Eleanor reservoir would also reach this point by flowing down Eleanor Creek to Cherry Creek and down Cherry Creek to the Tuolumne River.

It is to be assumed that at this point the river water will rarely, if ever, be turbid. The diversion will, therefore, probably, be practically continuous. Suitable provision for keeping drift out of the conduit and for sluicing out sand deposits will, however, be made. The water taken out of the river will be carried in canal and tunnel, with occasional inverted siphons (as across the cañon of the South Fork), about 28 miles to a mountain spur from which, in a distance less than 2 000 ft., a drop of 766 ft. is available for the generation of power. This is at Bear Gulch.

Below Bear Gulch the canal will be cut into the mountain slope on the south side of Tuolumne River at an elevation about 350 ft. above the water surface of the river. The conduit at Moccasin Creek will be an inverted siphon of iron pipes about a mile long. When Red Mountain Bar is reached Tuolumne River will be crossed, also in iron pipes forming an inverted siphon. The water discharged by this siphon on the right or northwesterly bank of Tuolumne River will flow a short distance, about 640 ft., in an open canal. It will then enter a tunnel 2 660 ft. long, will be piped across a depression 4 450 ft., will enter another tunnel 1 130 ft. long, will be piped across another depression, and will then enter a tunnel 11 430 ft. long that will discharge it into the watershed of Dry Creek. A short canal will carry it to a point from which it can be dropped 330 ft. to the elevation selected for the head of the pipes across the San Joaquin Valley.

Both the drop at Bear Gulch of 766 ft. and that at Dry Creek of 330 ft. are to be utilized to generate power which can

be transmitted electrically across San Joaquin Valley and there utilized to pump the water over the Livermore pass at Altamont. Suitable power installations are to be made for this purpose. It will not, however, be necessary to erect a power station at Dry Creek so long as only a part of the water arriving at Bear Gulch will be required for use in San Francisco. Power generation may thus, for many years, be confined to the single station.

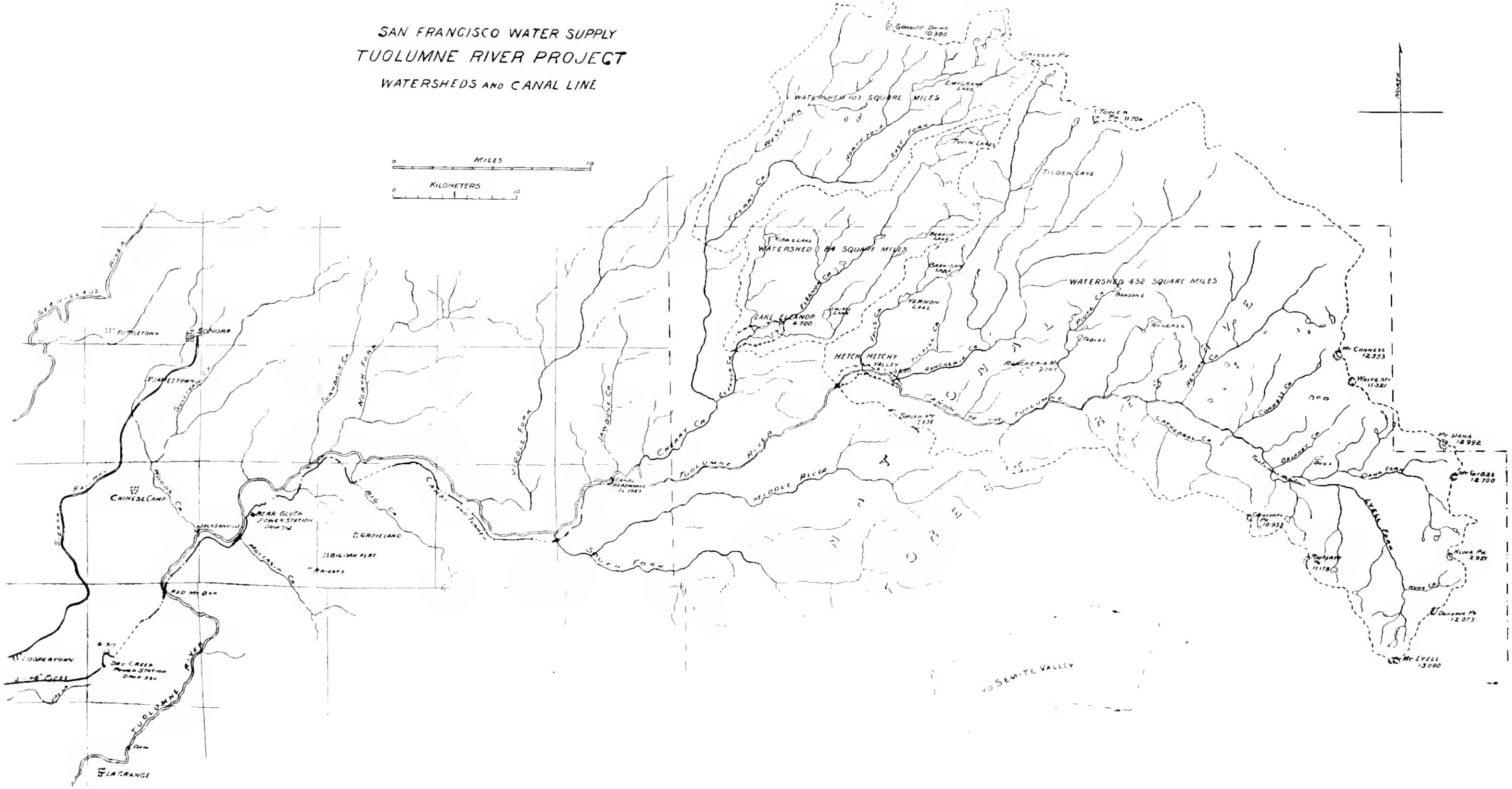
The surplus water there used for power will be a part of that which would under any circumstances have been allowed to flow in the river to La Grange for the irrigation canals.

After passing the Dry Creek power station the water will be delivered into the San Joaquin Valley pipes from a small reservoir. Local run-off is to be excluded from this reservoir, and it will be equipped with adequate outlet structures to screen and control the water flowing into the pipes and to drain the reservoir when necessary. The water surface in this reservoir is to be at 567 ft. above city base.

Across the San Joaquin Valley, in a direction almost due west, the water will be carried 60.5 miles in riveted pipes 48 in. in diameter. Stanislaus River will be crossed on a bridge, a long stretch of land subject to occasional overflow will be crossed on a trestle and the San Joaquin River, which at certain seasons of the year is navigable, will be crossed in submerged pipes. The project as outlined made provision for two 48-in. pipes across the San Joaquin Valley. In case that the Tuolumne project is to supplement the Spring Valley system, only one pipe would at the outset be required, and this would perhaps be of some other diameter probably somewhat larger.

The San Joaquin Valley pipes will discharge into a receiving reservoir at the Altamont pumping station, and from this reservoir the water is to be pumped over Livermore Pass. The receiving reservoir will be at elevation 155 ft. and the Altamont reservoir at elevation 740 ft. above city base. Allowing for the friction in the force mains, the pressure at the pumps will be equivalent to a head of about 625 ft. The pumping plant is to be of high duty, arranged for operation with electrically transmitted power. Some steam power is to be held in reserve for use in emergency.

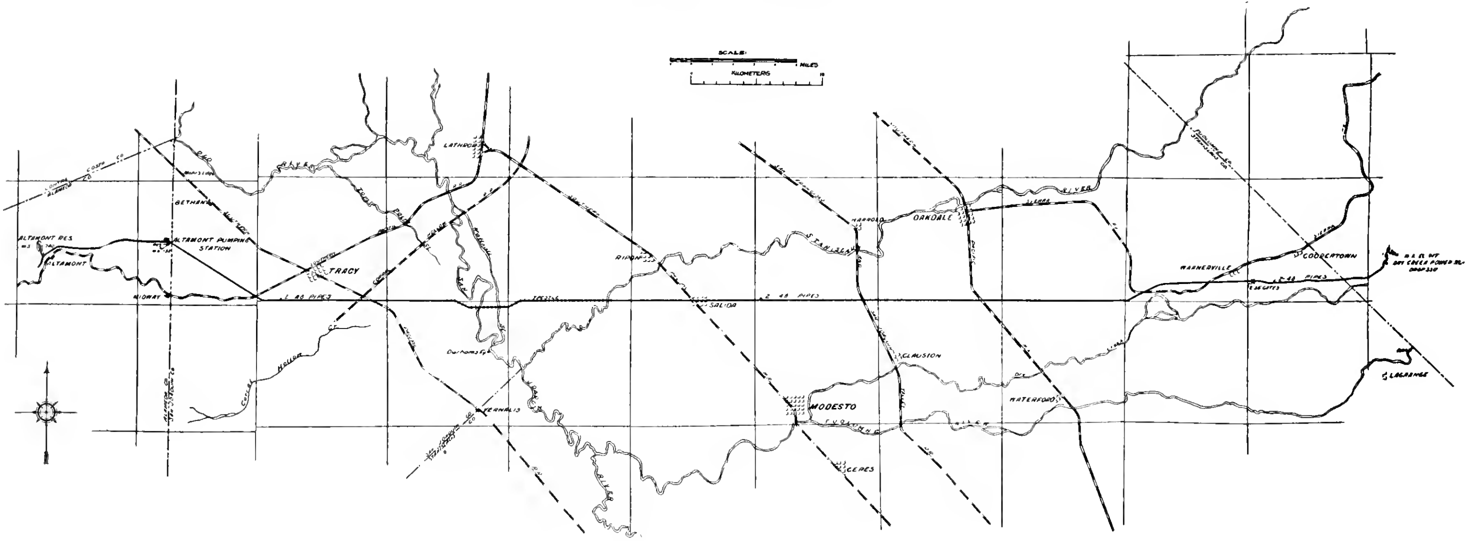
On the summit at Livermore Pass the water will be discharged into the Altamont reservoir, which is to have a capacity of about 200 000 000 gal. This reservoir is at the head of the long line of pipes in which the water will be carried into

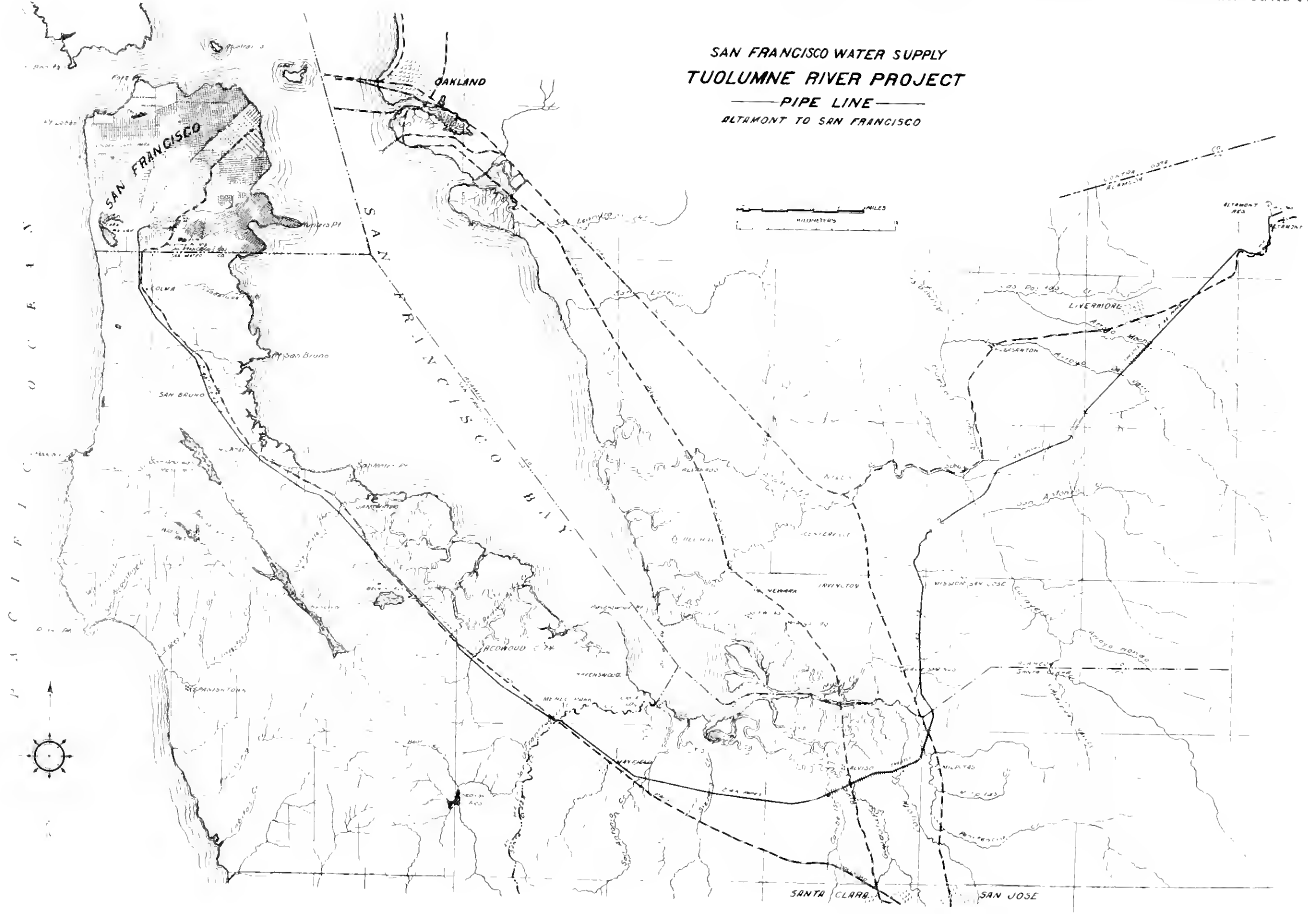

SAN FRANCISCO WATER SUPPLY
TUOLUMNE RIVER PROJECT
WATERSHEDS AND CANAL LINE
MILES
KILOMETERS
NORTH
WATERSHED 103 SQUARE MILES
WATERSHED 84 SQUARE MILES
WATERSHED 452 SQUARE MILES
LAKE ELEANOR
HETCH HETCHY VALLEY
CAÑON OF THE TUOLUMNE
TUOLUMNE RIVER
MIDDLE RIVER
SOUTH FORK
CANAL AND TUNNEL
CHERRY CR.
ELEANOR CR.
MIDDLE FORK
NORTH FORK
TURNBULL CR.
JAWBONE CR.
BIG CR.
MOCCASIN CR.
WOODS CR.
SULLIVAN CR.
STANISLAUS RIVER
SONORA
JAMESTOWN
TUTTLETOWN
CHINESE CAMP
JACKSONVILLE
BEAR GULCH POWER STATION
GROVELAND
BIG OAK FLAT
PRIESTS
RED MT. BAR
COOPERTOWN
DRY CREEK POWER STATION
LA GRANGE
TUOLUMNE RIVER
VERNON LAKE
TILDEN LAKE
TWIN LAKES
EMIGRANT LAKE
GRANITE DOME 10300
MT. CONNESS 12353
WHITE MT. 11321
MT. DANA 12992
MT. LYELL 13090
CATHEDRAL CR.
LYELL FORK
DANA FORK
YOSEMITE VALLEY

SAN FRANCISCO WATER SUPPLY

TUOLUMNE RIVER PROJECT

PIPE LINE ACROSS SAN JOAQUIN VALLEY




SAN FRANCISCO WATER SUPPLY
TUOLUMNE RIVER PROJECT
PIPE LINE
ALTAMONT TO SAN FRANCISCO
MILES
KILOMETERS
OAKLAND
SAN FRANCISCO
SAN FRANCISCO BAY
PACIFIC OCEAN
Hunters Pt
COLMA
Pt San Bruno
SAN BRUNO
LIVERMORE
ALTAMONT
REDWOOD CITY
MENLO PARK
MAYFIELD
SANTA CLARA
SAN JOSE
MISSION SAN JOSE
CENTERVILLE
NEWARK
IRVINGTON
ALVISO
Arroyo Hondo

and across Santa Clara Valley. The route of the conduit will be westerly through the Livermore Valley across a ridge of hills between Valle and Calaveras creeks, where there will be a tunnel 1 mile long, thence crossing the Calaveras Creek and over the ridge west of this creek into the Santa Clara Valley. At the point where Santa Clara Valley is reached a drop of 80 ft. is practicable. It may, upon further study, be found desirable to utilize all of this extra head in the conduit, thereby reducing the size of pipes somewhat. Under the project as outlined in the official report, here (as across the San Joaquin and Livermore valleys) two lines of 48-in. riveted iron pipe each with a capacity of 30 000 000 gal. will be requisite. The route of these pipes will be around the southerly end of San Francisco Bay and thence northwesterly and northerly to an entrance into San Francisco by way of Colma. The location of the main supply pipes within San Francisco will be on the westerly slope of the main peninsula ridge, at an elevation between 200 and 220 ft., to the Ocean House road; along this road a short distance, thence by tunnel to the easterly side of the ridge at about elevation 214 ft.

For a system of water works, with Tuolumne River as the sole source of supply, it would be necessary to provide storage facilities somewhere near San Francisco for at least a 30-day supply. Much more would be desirable, because the water works of a large city should be amply safeguarded. No large reservoir site in or near San Francisco has been discovered at sufficient altitude to permit delivery of water from it to San Francisco by gravity flow. The best site that has been discovered is located near Belmont. By means of a dam rising to a height of about 105 ft. above the present surface of the ground, water can there be impounded to the extent of 3 000 000 000 gal. — a 50-day supply when the water consumption of the city has reached 60 000 000 gal. per day. The water surface in this reservoir would be at elevation 177 ft. above city base, not high enough to flow over the divide near Colma.

The Belmont reservoir would be filled from the Tuolumne mains and the water there stored would in the case of an emergency be pumped into San Francisco through the northerly section of the main pipes. Under the project as outlined a pump capacity of 30 000 000 gal. per day was proposed for this point.

(Tuolumne) Distribution System.

There would be two receiving reservoirs in San Francisco,

one with a capacity of 100 000 000 gal. on the House of Refuge lot, at the intersection of San José and Ocean avenues, and another east of Mission Road, just south of Amazon Avenue. The arrangement of the discharge into the receiving reservoirs is to be such that the full volume of water reaching the city can be sent into either of them. The elevation of these reservoirs would be 196 ft.

The distributing system that would be necessary for the water arriving in the city as described was carefully studied. To maintain adequate pressure, and yet avoid excessive pressure in the pipes, it was found desirable to arrange the water distribution in 5 levels, of which the low level alone was to be served by gravity flow direct from the receiving reservoirs. All other levels were to be served from two pumping stations, one located in the block bounded by Seventeenth, Eighteenth, Diamond and Eureka streets, and the other located near the House of Refuge receiving reservoir.

On the low-level system there were to be three reservoirs and two tanks with a combined storage capacity of 26 912 000 gal.

On the second level there would be two reservoirs and two tanks with an aggregate storage capacity of 29 830 000 gal.

On the third level there would be one reservoir and seven tanks with an aggregate storage capacity of 3 233 000 gal.

On the fourth level the storage to be provided in three tanks would be 1 448 000 gal.

On the fifth level in two tanks storage to the amount of 1 300 000 gal. would be provided.

The combined storage capacity of all the reservoirs on the city distributing system, including the two receiving reservoirs, would be 218 343 000 gal.

It is not necessary to describe the distributing system in detail. This paper would become too long if this were attempted. The diagrams and general location maps further illustrate the salient features of the project. It should, however, be stated that the distributing system of reservoirs, pumping plants and interconnecting pipes of the Tuolumne River project were planned to meet fully the requirements of the city. On this subject the report of 1902 may be quoted: " At the special request of the Fire Department, the smallest pipes on main streets have been planned 8 in. in diameter. This is in some cases, perhaps, in excess of immediate requirements, but as the pipes laid would serve from 50 to 100 or more years, and the additional cost involved is small, it was thought advisable to

comply with this request. The smallest mains in streets of secondary rank, and where only one or two fire hydrants are to be served, are to have a diameter of 6 in."

The distributing system thus planned would have been superior to the pipe system and reservoirs now in service. However, in the report on the Tuolumne River project, in discussing the same as a project to supplement the established works, the writer says:

"The city distributing system [of the Spring Valley Water Company] would come into use without modification, except the placing of larger mains in some sections of the city to insure the best possible fire protection, and the construction of a number of new reservoirs and tanks and an improvement of the pumping facilities. It is thought that an expenditure of $1 000-000 in betterments of this kind would be at once justified if the Spring Valley Water Works were augmented by a supply from the Sierra Nevada, and that about $500 000 would cover the cost of the receiving reservoir at the House of Refuge lot, and its service mains."

(Tuolumne) Purity.

In the progress report already referred to, after quoting Col. G. H. Mendell's favorable opinion of the high mountains of the Sierra Nevada (3 000 or 4 000 ft. upward to the summit ridge) as a source of water for municipal use, the writer says:

"Further observations have confirmed this view, and from personal examinations of the drainage basins of the rivers descending these western slopes, from the Yuba southward to the Merced, it is to be added that in other respects some of these drainage basins are ideal drainage grounds for a city water supply. The snow which accumulates during the winter and is not all melted until midsummer performs the same function as storage reservoirs, equalizing the flow of the rivers. The severity of the climate and the ruggedness of the regions of high altitude in the Sierra Nevada render them uninhabitable, and, it might almost be said, inaccessible for the greater portion of the year. Great areas, particularly southward from the drainage basin of the Stanislaus River, have in the past been accessible for pasturage only to a very limited extent, and they are now still protected against occupancy by man by being made national parks and forest reserves. The high Sierra is a region of granites, slates and lava, much of it bare, not yet covered with soil. Over vast areas the recent action of glaciers is traceable.

"The polished striated surfaces of the granite still glisten in the sunshine. Hundreds of small lakes have been carved out of the original surface of the country by the glacial action, notably in the region which includes the headwaters of the

Stanislaus, Tuolumne and Merced rivers, and the other streams of the Sierra Nevada further to the south. Other lakes are formed, in part at least, by the terminal moraines of glaciers, which have been left as barriers across the original outlets of valleys . . . " Throughout the high mountain region, and particularly in those portions thereof which show marked glacial action, lakes, as already stated, are numerous. Some of these are of considerable size, among the best known being Blue Lakes, Lake Eleanor and Lake Tenaya. The water of these lakes is, almost without exception, of remarkable purity. A large number have been personally visited and no reason seems apparent why the water of those of the glaciated, uninhabited high mountain regions southward from Lake Tahoe should not be considered equal in quality or even preferable to the water of Lake Tahoe, around which there will always be more or less marginal land available for human occupancy and desirable as a summer resort."

The quality of the water obtainable from Tuolumne River may be judged from the analyses made by the city chemist, Mr. Frank T. Green, in 1903.

Two samples of water were taken in sterilized large bottles by a chemist, Mr. J. H. Gray, acting under the writer's direction, the one from Lake Eleanor on September 30, 1903, the other on the same day from Tuolumne River in Hetch Hetchy Valley. The river was at that time at a low stage. The sample from the lake, it was thought, might be regarded as typical of the water that would be held in the enlarged Eleanor reservoir and in the proposed Hetch Hetchy reservoir. The results of the analysis were favorable, as will be seen from the following, submitted by Mr. Green under date of November 7, 1903.

	Lake Eleanor. Parts in 100 000.	Tuolumne River. Parts in 100 000.
Total solids	1.4	3.0
Loss on ignition	0.4	0.4
Fixed residue	1.0	2.6
Chlorine as chlorides	0.198	0.357
Oxygen consumed	0.132	0.07
Nitrogen as albuminoid ammonia	0.006	0.005
In first 50 cu. cm.	55%	53%
In second 50 cu. cm.	37%	26%
In third 50 cu. cm.	8%	13%
In fourth 50 cu. cm.		8%
Nitrogen as free ammonia	0.004	0.0024
In first 50 cu. cm.	50%	77%
In second 50 cu. cm.	34%	18%
In third 50 cu. cm.	16%	8%
Nitrogen as nitrites	0.00003	0.00004
Nitrogen as nitrates	0.0024	0.0012

QUANTITATIVE (ACIDS AND BASES).

PARTS IN 100 000.*

	Lake Eleanor.	Tuolumne River.
Total solids	1.40	3.00
Fixed residue	1.00	2.60
Silica, SiO_2	0.307	0.567
Magnesia, MgO	0.028	0.060
Iron and alumina, Fe_2O_3, Al_2O_3	0.017	0.057
Lime, CaO	0.127	0.377
Sulphur trioxide, SO_3	0.101	0.131
Sodium chloride, $NaCl$	0.327	0.590
Carbon dioxide and undetermined	0.093	0.818

CALCULATED INTO SALTS.

PARTS IN 100 000.

Calcium sulphate, $CaSO_4$	0.1717	0.222
Calcium carbonate, $CaCO_3$	0.1014	0.509
Magnesium carbonate, $MgCO_3$	0.0588	0.126
Sodium chloride, $NaCl$	0.3270	0.590
Silica, SiO_2	0.3070	0.567
Iron and alumina, Fe_2O_3,Al_2O_3	0.0170	0.057
Undetermined	0.0171	0.529

It is reasonably certain that Tuolumne River at its high stages would show still less of total solids in solution.

The following analysis of a sample of Lake Tahoe water, taken on October 16, 1900, was made by Mr. J. H. Gray, acting under the writer's direction. It is noted for comparison and to show the general excellency of the waters originating in the high mountains of the Sierra Nevada.

LAKE TAHOE WATER.

PARTS IN 100 000.

Total solids	6.5
Loss on ignition	1.5
Fixed residue	5.0
Chlorine	0.142
Nitrogen as nitrites	None
Nitrogen as nitrates	Trace
Nitrogen as free ammonia	0.0006
Nitrogen as albuminoid ammonia	0.0034
In first 50 cu. cm	71%
In second 50 cu. cm	23%
In third 50 cu. cm	6%
Oxygen consumed	0 010
Bacteria at 100 yds. off shore per cubic centimeter	1
Bacteria at 200 yds. off shore per cubic centimeter	0
Bacteria at 300 yds. off shore per cubic centimeter	0
Bacteria at 500 yds. off shore per cubic centimeter	0

* One Liter, the quantity used for each estimation, except in case of sulphates, then 500 cu. cm.

The water for the bacteriological examination was taken at a later date. It was plated immediately upon being taken and the results noted are considered reliable.

A sample of water for bacteriological examination from near the lake outlet taken at the same time that the samples for chemical analysis were taken showed a few bacteria (60 per cubic centimeter are recorded, page 344, Appendix Municipal Reports of San Francisco, 1900–1901), but it is noted (on page 379) that the determination of the number of bacteria should be ignored because immediately after the samples were taken a light flaky substance was noticed in the water, and because a delay in transportation occurred, making the time two days before the samples reached the laboratory.

Analyses of the waters that were being furnished to San Francisco in 1900 and 1901 by the Spring Valley Water Works were also made. The results are published in the Municipal Reports of 1900–1901, Appendix page 353 *et seq.* Later analyses in large numbers have been made by the city chemist under direction of the board of health.

(Tuolumne) Cost.

In 1902 a cost estimate was made of water works with Tuolumne River as the sole source of supply. The capacity of the works, which were made the basis of the cost estimate, was 60 000 000 gal. per day. The money, to be raised by a bond issue, was estimated at $39 531 000. This includes $8 807 000 for a distributing system. Interest during construction was not included because no part of the interest on the bonds would be paid out of the construction fund resulting from the sale of bonds.

Six years have elapsed since the cost estimate was made. Since that time the country has been swept by a wave of prosperity attended by a material increase of prices of materials and of wages and this wave has been followed by a period of more or less business depression attended by falling prices of materials and by a lower wage scale. The cost estimate, therefore, needs some revision. This revision and a suitable adjustment of the works to altered requirements would be all the more necessary if the project is to be so modified that it will supplement the Spring Valley system.

The cost estimate of the Tuolumne River water supply project, made by the writer as city engineer, was based on surveys and examinations covering all parts of the project. The

reservoir contents were determined from contour lines surveyed by the United States Geological Survey. The dams at Lake Eleanor and across the Tuolumne River at the lower end of the Hetch Hetchy Valley were planned after the sites had been surveyed and examined in person. The route for the canal and tunnels and pipe lines was surveyed throughout. The distributing system in the city, including receiving and distributing reservoirs and pumping stations, was worked out in sufficient detail to show location and plans of proposed structures and the complete network of pipes required. The maps and diagrams that were prepared to illustrate the project and to accompany the report were 36 in number. They are enumerated in the letter transmitting the Tuolumne River report. This enumeration does not, however, include the plane table survey sheets, of which there were a large number showing the conduit route.

In the water rate cases still pending, the engineer experts of the Spring Valley Water Company call attention to the underestimate of the cost of the proposed Tuolumne River project. These experts all testify to the need of carrying the water from the proposed point of diversion from Tuolumne River, — in fact, from the mouth of Cherry Creek some miles further upstream, — to San Francisco in covered conduits. Reservoirs, notably the Hetch Hetchy itself, which is located in the mountains at an altitude of 3 600 ft., are referred to as exposed to the hot sun, and this is noted as detrimental to the water quality. These criticisms are made, first, to discredit the superior quality of the mountain water as delivered, and, second, to establish a high cost of works for purposes of comparison with the Spring Valley system.

Among the engineers who have thus declared it to be necessary to cover the proposed open canal are Mr. F. P. Stearns and Mr. Jas. D. Schuyler. Their testimony is best refuted by quotations from a report in which they both joined a few months later.

Mr. Stearns, testifying in 1905 relating to the open canal section of the Tuolumne project, says:

"In an unlined open canal on a steep hillside, as in this case, water would deteriorate in quality both by its exposure to the sun in the shallow canal and by opportunity afforded for the pollution of the water; some would be lost by filtration, and such a canal would be more liable to accidents and interruption than a tunnel. It would seem to me advisable, in view of the very great length and cost of the work, that this portion should be built wholly in tunnel, fully lined, so that the works would

be less liable to interruption and to the liability of pollution and deterioration of the water which I have spoken of."

Mr. Schuyler in the same connection says:

"I do not believe that the water would maintain its purity after it left the headworks unless the scheme as outlined by him were to be materially changed and the water carried throughout in closed conduits. The proposition of carrying the water for 27 or 28 miles in open ditches along the mountain sides is one which must necessarily lead to constant pollution of the supply, not only from matter picked up from the bed and banks of the canal as it passes along, but it would be exposed to the action of the sun throughout that distance and subjected to the pollution from the drainage of the pastures through which it passed and subject to pollution from the wash of the mountain sides in storms and also from landslides from the mountains; the blowing of dust and leaves and other matter borne by the winds and deposited in the canal would further add to the pollution of the water."

Most of this open canal is to be along steep hillside. The following extracts are from the city engineer's report of 1902:

"The bottom width of the canal will be 9 ft.; the proposed depth of water 5 ft." "Rain water accumulating on the hill-sides above the canal is to be intercepted by a proper system of small ditches which will lead the water into ravines for which a crossing over or under the canal will be provided in each case as may be best adapted to local conditions."

After flowing down the Tuolumne River some 16 miles, and then in conduits, of which about 28 miles are of the uncovered type, the water will pass through two small reservoirs at the head of the Dry Creek power station, through a small reservoir at the head of the San Joaquin Valley siphon, through a small reservoir at the Altamont pumping station, through a reservoir having a capacity of 206 000 000 gal. at Altamont summit, besides 152 miles of tunnel and pipe, and if it should be thought desirable, can be made to flow through the proposed Belmont reservoir whose capacity is estimated at 3 000 000 000 gal., though this would involve some additional pumping.

With these facts in mind Messrs. Stearns and Schuyler may be again quoted. They joined with Mr. John R. Freeman, in a report dated December 22, 1906, on the project now accepted of supplying Owens River water to Los Angeles through a conduit 231 miles long. They say in this report:

"Our examination of the streams in the Owens Valley showed that the creeks coming from the Sierras furnished water which is clear, colorless and attractive; the water in the river,

being made up of the combined flow of these creeks, is of similar character, but has a slight turbidity and stain, owing apparently to drainage from the marshes in Long Valley and to other return water from the canals and irrigated lands. This feature would make the water somewhat objectionable if it were to flow directly from the river into the city pipes, and [but] it has little or no significance in the present instance where the water, after being taken from the river, is to be held for a long time in a large storage reservoir where the mineral particles which produce the turbidity will have time to settle. The long period of storage in the reservoir will also be an important safeguard against the transmission of disease germs should any enter the water of the river, because it has been found, both by experiment and experience, that disease germs are all, or nearly all, destroyed where the water is held sufficiently long in reservoirs."

The Los Angeles conduit, as recommended by the engineers above named, will be an open canal for 20 miles in Owens Valley; thence, still in this valley, for 40 miles it will be an open canal lined on bottom and sides with masonry laid in Portland cement. The next 15 miles of the conduit are also to be of the open type lined with masonry. In the following 24.5 miles there will be a reservoir of tunnels, siphon pipes and sections of bench conduit along mountain sides, the latter covered at the outset with reinforced concrete. Then come 20 miles of open, lined canal of easy excavation, with less than 4 000 ft. of steel flumes and pipes crossing dry wastes. All of the next 21.5 miles of the conduit will be under cover. The canal then emerges upon the smooth plains of Antelope Valley and will be lined, but without cover, for 64.5 miles. This stretch of the conduit is followed by a tunnel nearly 5 miles long to San Francisquito Cañon. The water is to flow down this cañon 11 miles until its use for power development becomes sufficiently important to justify the substitution of an artificial conduit. From San Francisquito Cañon to the head of the San Fernando Valley the water will be carried 15.18 miles in tunnels, siphons and covered canal.

Of the 164.5 miles of the lined section of the Los Angeles aqueduct, 19.8 miles are to be put under cover. The rest of the lined sections, 144.7 miles, are to be left open for the first five years of operation. The 22.2 miles of unlined canal are to remain open permanently, and the 11 miles of natural water course for an indefinite period, to say nothing of the flow of the water for many miles in Owens River above the proposed point of diversion.

The consulting engineers say of this project: "We find the project admirable in conception and outline, and full of promise for the continued prosperity of the city of Los Angeles."

Compared with Owens River the Tuolumne River is a far more desirable source of supply. Are not, therefore, the same words of praise applicable to the Tuolumne River project, in so far as the source of supply and the compared features of the project are concerned?

It is not necessary to notice other criticisms of the Tuolumne River water supply project by the engineer experts who testified for the Spring Valley Water Company. These, particularly such as those relating to the city engineer's failure to include in his cost estimate interest during the construction of the works, must be assumed to have originated in a desire to show a probable high cost for any system of water works independent of the Spring Valley system, in order that any weight given to a comparison with the cost of bringing in other water may be in favor of a high valuation of the Spring Valley Water Company's works. The matter of interest during construction is referred to in the city engineer's report, but was not included in the cost estimate to be used as a basis for a bond issue, because, as already stated, it was not proposed to make it a part of the bond issue. It is admittedly an expense connected with water works construction, but in the case of a municipality the fund out of which to pay it originates in the tax levy and is not a part of the fund resulting from sale of bonds as is usually the case when private corporations proceed with construction of works under a bond issue. Its omission from a cost estimate which was to serve as a basis for a municipal bond issue was not, therefore, an oversight.

Succinct Statement of Conclusions.

In weighing the merits of sources of water for the supply of San Francisco particular attention must be given to the following points:

The quality of the water.

The quantity of water that can be made available.

The reliability of the service.

The cost.

The main consideration is quality. The water supplied to a municipality must be pure and wholesome. It should be above suspicion. The best water within reach of San Francisco, in the light of all the information now available, is the water of the high Sierras. In the Sierra Nevada Mountains there are great areas of uninhabitable territory. Regions are there to be found to which human activities are not likely to be attracted,

and of these, many, by inclusion in national forest reservations and parks, will receive federal protection against invasion by any undesirable activity. These regions are, in part at least, of the bare granite type at high altitude. A careful study and exploration of these regions from Yuba River southward to the Merced River has led to the selection of watersheds on the headwaters of the Tuolumne River as the most desirable producing ground for water for San Francisco. Some of the facts that compel this conclusion may be briefly reviewed. Not one of the Sierra Nevada rivers, except Feather River, has a summer flow which would be adequate to meet the requirements of San Francisco in the matter of sufficiency of supply. But Feather River is out of consideration by reason of the remoteness of this source, the disadvantage of a conduit route that would cross the straits of Carquinez and the Bay of San Francisco, and the unfavorable collecting ground of the water, the vast extent and accessibility of which would render it impossible to exclude human habitations.

Water storage may, therefore, be set down as a requisite feature of any Sierra Nevada water project.

This having been determined, it is natural that the first thought should be of Lake Tahoe as an ideal source of water. No fault can be found with the quality of the water in the lake, which has a surface area of 250 sq. miles and is fed by the run-off from 250 sq. miles of high surrounding mountains. The mean annual outflow from the lake, through Truckee River, is equal to a layer of water 17 in. deep over the lake surface. This would be adequate for a population of about 2 000 000 people. Moreover, this water production could be increased somewhat by adding the water of Rubicon Creek, making an interconnection between a small reservoir on Rubicon Creek and the lake by tunnel, in which water would flow into or out of the lake according to whether the creek were producing more or less water than conduit capacity to the city. But there are riparian rights around Lake Tahoe and improved properties on the lake shore, there are acquired rights to the flow of Truckee River for various purposes, and, moreover, full use is to be made of the entire stream flow in Nevada for irrigation. The superior use of the water for a municipal supply might be difficult to establish, particularly as the lake, and the watershed tributary to the lake, lie in two states and the flow from the lake is into the neighboring state, Nevada. So long as other adequate sources of supply in the Sierra Nevada are available, Lake Tahoe may, therefore, be dismissed from consideration.

Yuba River has received due consideration in the water supply investigation, more perhaps, than this river deserved. The same objection to location applies as in the case of Feather River. The water would be under suspicion of contamination and should be filtered before use. As in the case of a Feather River project, the crossing of the Bay of San Francisco is a feature that weighs heavily against the project.

American River comes under consideration on the same basis as the remaining Sierra Nevada streams. Its low water flow is already appropriated and in use for various purposes. Water to be made available on this stream must be impounded in reservoirs. Sites for large reservoirs, located so that they can be filled, have not been found in the high mountains. Long conduits of large capacity to low mountain basins, where local undesirable run-off complicates the problem, become features of the various American River projects. The high mountain area that belongs in the class that can be permanently preserved in an uninhabited condition is relatively small. This river, therefore, is less attractive than the Tuolumne, to which these objections relating to storage facilities and protection of watersheds do not apply.

Cosumnes River has, properly speaking, no high mountain watersheds.

Mokelumne River, under coöperation of water power companies, which control the situation, can be made available, but storage will be scattered in a large number of relatively small reservoirs and there will be much human activity in some of the areas tributary to the storage sites. It offers no such cleancut and attractive project as that outlined for the Tuolumne River.

On the Stanislaus River there are fair opportunities for storing water, but they are scattered and are, in part at least, already in use to supply water for power and other useful purposes. There is no place known on this stream where there is any approximation to the advantages offered by such a site as Hetch Hetchy Valley on the Tuolumne River.

In the case of Tuolumne River, as has been pointed out, exceptional facilities exist for storing water. Two sites were selected for the city of San Francisco. Both of these, and the tributary watersheds, are within a national forest reservation. Both are high enough in the mountains to exclude from tributary watersheds the undesirable lower lying mountain slopes. Their combined storage capacity, as originally planned, is about 45 000 000 000 gal. of water. This can be doubled by making

the dams higher. Where the river below these dams will carry the water to a point of diversion, the river lies in a deep cañon and its accessions are from small timbered mountain areas. Should it ever become desirable to exclude parts of these watersheds below the main reservoirs, this can be done by extending the headworks farther upstream. The fact that the divide between the main fork of the Tuolumne and the South Fork above the selected point of diversion lies very close to the main stream is a favorable feature; there will probably never be any south side run-off, except local hillside waters, to be excluded. On the north side of the main stream, Cherry Creek drains a region which is throughout acceptable as a tributary watershed. The only other stream of note coming in from the north is Jawbone Creek, on which, in the course of time, lumber interests may concentrate sufficient population, for a time at least, to make its exclusion desirable. A short extension of the canal upstream (about 1½ miles) would accomplish this.

The route for a conduit to bring the water from Tuolumne River to San Francisco is practicable and has, as stated, been surveyed. It includes a very long pipe line, but this, as is well known, is a necessary feature of any project for a water supply from the Sierra Nevada.

San Francisco has now advanced to the point where she controls storage sites in which abundant storm water from high mountain watersheds may be impounded to meet the needs of the growing city for many years. The secured source of supply can be used to supplement the Spring Valley system, or the water can be brought to the city in independent water works.

The city must now determine whether to adopt any or none of the following methods of procedure:

1. Continue as at present, water to be supplied by the Spring Valley Water Company at a fair compensation, and the works to be expanded to other sources as the needs of the city demand.

2. Construct an independent system of works with the Tuolumne River as a source of supply.

3. Acquire by purchase the established water works and add thereto, as a first enlargement, water from Tuolumne River.

The disadvantages of the first course of action have been made plain by experience. It will continue to involve the city in an annual wrangle with the water company concerning rates. The water company will, as in the past, find it difficult to extend its works as rapidly as good judgment would indicate

to be desirable. The probability will be that other near-at-hand sources of supply will be added before the works will be extended to any Sierra Nevada source.

If the city constructs a municipal system of water works as an opposition plant to the established works, the outcome will be that the value of most of the properties of the Spring Valley Water Company will be destroyed. This is particularly true of such portions of the works as cannot be used for other purposes than the supply of water to San Francisco. Operation by the company in opposition to the municipality is entirely out of the question. The rate payers will quickly learn that what they do not pay to the city in water rates must be paid in taxes. The private company could not name rates low enough to hold consumers, particularly when quality of water is considered. But the construction of a system entirely apart from the old has its disadvantages. The pipe system in the city streets would have to be duplicated, and some 50 000 house connections would have to be made at large expense to the property owners. The construction of a new system of pipes extending along every street would do no small injury to street pavements. Should the company desire to save any pipe by removal from the ground this might mean a duplication of much of the trenching. There would not be as much nearby storage as desirable.

Now that the city is ready to move in the matter of acquiring a system of water works, the only one of the three courses above enumerated that seems advisable lies along lines indicated in No. 3. The city needs certain things which the Spring Valley Water Company has, and it needs some of them most decidedly.

The city needs the distributing system of the water company, pumps, reservoirs, tanks and pipes without reservation. The city needs the peninsula storage system, Pilarcitos, San Andres and Crystal Springs reservoirs and watersheds. The city needs the pipe lines from these reservoirs to the city and the receiving reservoirs. The city needs Lake Merced as an emergency source of water, and it needs the Merced lands for park purposes. The city needs all of the properties of the water company, particularly if it should be found desirable to unite with other municipalities in the control of all nearby sources of water, and in the addition of a supply from the Sierra Nevada.

The city, if it become the owner of the water company properties, can continue the operation of the water works and

make suitable provision for the increasing demand for water during the time the Sierra Nevada works are under construction.

If the city, on the other hand, enters upon the construction of independent water works, it must be expected that the Spring Valley Water Company will curtail expenditures as much as possible, refraining particularly from new construction, and as a result there may be some years before the new works come into service in which the water supply will prove deficient.

In case that the course, which has been pointed out to be the natural one, be followed, the first step to be taken will be to reach an agreement with the Spring Valley Water Company concerning the price at which its properties will be sold to the city. It will then be possible to outline a water supply project based upon the works as now in service, supplemented by a water supply of prime quality from the Tuolumne River, developed at the points where the city has already acquired rights of storage.

Again quoting from the writer's report on available sources of water, dated November 24, 1902:

"Expense, so long as the same is within reason and not a burden upon the community, should not be spared in obtaining the best water that may be had."

There should be no hesitation, first, in acquiring the present water works, if this may be done at a fair price, and second, in reaching out to Hetch Hetchy Valley and Lake Eleanor for an additional supply.

[NOTE. Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by December 15, 1908, for publication in a subsequent number of the JOURNAL.]

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PRESSURE FLUCTUATIONS IN TURBINE PIPE LINES.

BY PROF. A. BUDAU, ENGINEER, VIENNA, AUSTRIA.

[Translated from the German and partly read by Heinrich Homberger, Member of the Technical Society of the Pacific Coast, before the Society, March 20, 1908.]

THE progress in utilization of water power frequently compels the engineer to transfer his work from the inhabited valleys to rough mountain regions where, of the two factors of hydraulic energy, viz., head and quantity of water, at least the former is available in abundance.

The utilization of water power with high head, however, offers some difficulties. To obtain a high head, most frequently a long ditch is required whose construction is made difficult by unfavorable topographical conditions and obstructions to transportation. Next to this, in most cases, comes a very long pipe line which forms a very disagreeable link in the complicated mechanism of an hydraulic power plant, because it not only means an increase of first cost of the plant, but also causes complications of operation.

Against freezing of the pipe, covering of same is only a scant protection. During the time of severe cold weather, water has to run through the pipes continuously; otherwise they will freeze, notwithstanding the covering; but even during the warm seasons a pipe line can cause difficulties if, as is always the case in these days, a very accurate speed regulation of the turbines is required.

The modern turbine governors open and close very rapidly. Ten years ago governors were not an exception which, in case of

complete drop of load, happening, for instance, as a result of a short circuit in the electric net, shut the turbine off in twelve to thirteen seconds; but the time of closing has been continuously reduced, especially since the so-called hydraulic governors have been adopted, which have stored energy available, and to-day, a closing time of two seconds for turbines of many thousands of horse-power cannot yet be taken as the lowest limit.

It is impossible to rapidly stop the flow of a large quantity of water offhand, and certain precautions have to be taken. It goes without saying that these precautions have to be most careful and most complete if the water is conveyed to the turbine in a long pipe line.

The discussion of such devices, and some theoretical investigations referring to same which a practicing engineer, on account of the absence of any guiding material in literature, must carry out to satisfy the responsibility thrust upon him; further, some experiences with long pipe lines, will constitute the contents of this paper.

If a certain quantity of water Q flows through a pipe line of the cross section F, the water in this latter will obtain a certain velocity v which can be calculated from the formula $v = Q : F$, if the quantity Q of water is known which flows through the pipe in a second. If the water is conveyed through the pipe line to a turbine, and H is the head from the head water level to the distributer of the turbine, immediately in front of the turbine a water pressure will prevail which is equal to $H - \frac{v^2}{2g} - \frac{\xi v^2}{2g}$, wherein ξ represents the coefficient of the pipe friction and g the acceleration of gravity. If now, while the water is flowing, its discharge from the distributer is suddenly stopped, a great rise of pressure will take place, especially at the lower end of the pipe line, and unless the pipes are elastic, their rupture will necessarily follow.

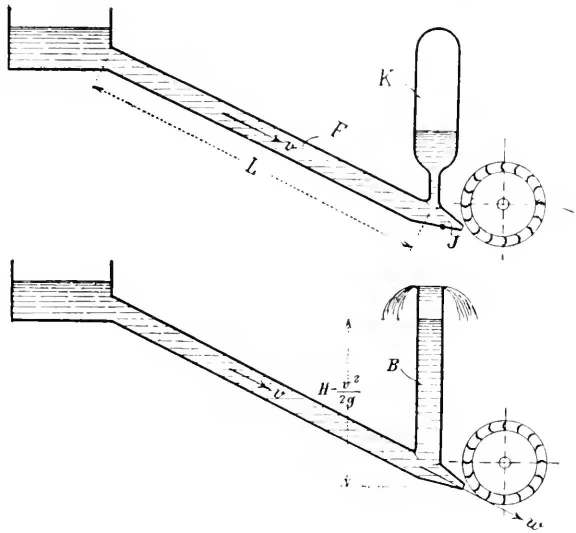
The water flowing in the pipe with the velocity v contains the energy A which cannot suddenly be destroyed and must necessarily express itself in deformations of the pipes. This energy, if L represents the length of the pipe line and F its cross section, expresses itself:

$$A = \frac{F \times L \times \gamma}{g} \quad \frac{v^2}{2} \qquad \text{I}$$

wherein γ represents the specific gravity of the water.

This rise of pressure, which, if occurring with considerable force, is feared in water mains as so-called hammer, one has

endeavored to reduce in turbine pipe lines by installing at the lower end of the pipe line an air chamber (Fig. 4) or a standpipe



Figs. 4 and 5.

B, also called free air pipe (Fig. 5), whereby the energy of the water flowing in the pipe line was to be given an outlet, compressing the air in the air chamber or lifting the water in the standpipe. Also safety valves have been applied.

There are, however, and especially in the most modern plants, by-passes or synchronous gates, devices which are operated simultaneously with the gate mechanism of the turbine so as to give to the water, which is held back when the turbine distributer is closed, an outlet into the tail water.

The writer advised such arrangements twelve years ago in a paper published in 1893 in the *Schweizerische Bauzeitung*. In the meantime, also, machines have been built where the non-utilized water passes through the distributer of the turbine, and such turbines, with combined distributer and free passage regulation, are designated as free passage turbines.

Standpipes are used under heads up to 100 ft., and economically only then if the topographical conditions are otherwise favorable. Air chambers have been frequently installed in former years; nowadays, however, they are not used any longer. Under the high pressure the water absorbs the air which is above it, and continuous refilling with air by means of specially provided compressors was found necessary, which soon became

cumbersome to the operators. One also hears, in some cases, that the governors operate better if the air chamber does not contain any air at all and is a water chamber only; and that the shocks of the water are not so bad as to cause any damage to the pipe, etc.

This, indeed, is logically correct, and it can be easily proved that air chambers themselves can become the cause of increasing periodical oscillations of the speed governors.

In a U-shaped bent tube (Fig. 1), let water be up to height H, which, of course, is equal in both legs. By some cause the water is brought into oscillation, and it will rise above the line ab in either leg alternatively, and fall below H. These oscillations of the water level in the two legs of the tube will last quite a while; in fact, they would not stop at all if there was no friction at the walls of the tube and between the particles of water themselves. The elevation of the center of gravity S of the water cylinder of the cross section F and the length h, or, in other words, the length h multiplied by the weight of the water cylinder, $F \times h \times \gamma$, gives the amount of energy which is contained in these oscillations and which also had to be contributed to the water to bring it into oscillation.

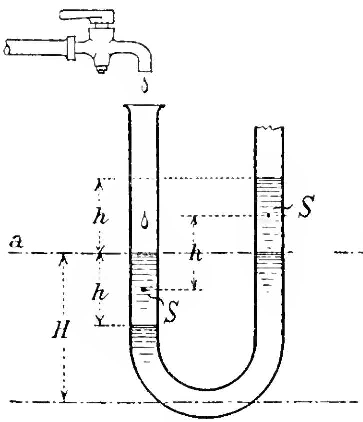


Fig. 1.

If now, while the water level is going down, a drop of water is allowed to fall into it, the height of oscillation h will be increased a small amount, and if frequently at the correct moment a drop falls upon the oscillating fluid, the oscillations of the water will increase until an overflow of water over the edge of the tube takes place.

The same will occur if one of the two legs of the tube is closed on top or if an air cushion is located above one of the water levels (Fig. 2), only in this case the oscillations h will be smaller and will only reach a certain maximum value, since the reaction upon the water level in the closed leg of the tube increases with increasing rise.

Also a moving water column can be brought into increasing

oscillations by continuous small impulses if it is connected with an air chamber.

Through the left leg of the U-shaped tube (Fig. 3), water is supposed to flow with a velocity v, discharging through a cock J.

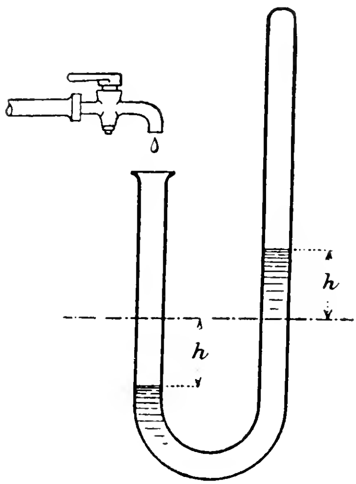


FIG. 2.

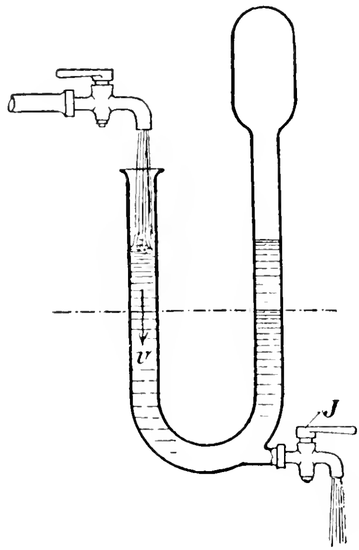


FIG. 3.

If now this cock is suddenly closed, a rise of pressure takes place which will cause a compression of the volume of air in the right closed leg of the tube, and the fluid, the flow of which is stopped, will be brought into oscillation exactly as in the previous case. If the cock J is not entirely but only partially closed, this will also cause an impulse to oscillate. There will also be oscillations which will be smaller than if the cock had been closed entirely, but which will last until the impulses of the particles of fluid against each other, and especially against the ones newly entering in the left leg of the tube, and further, the friction of the water on the walls of the tube, have used up the respective amount of energy.

If, for instance, the cock is only half open and be closed a certain amount every time when the water in the right leg rises, and then opened again, the oscillations can be raised to a maximum amount, the analytical calculation of which is not simple; but it will occur if the cock is alternately entirely opened and entirely closed.

Considering a high-pressure turbine provided with air

chamber and governor (Fig. 4), one can see immediately its analogy with the arrangement shown in Fig. 3. The regulating apparatus of the turbine has taken the place of the cock J in Fig. 3; the retardation of the flow in that moment at which the pressure rises, viz., when the water enters the air chamber K, is accomplished with the greatest accuracy by the speed governor. If, from any cause,— for instance, on account of shutting of a by-pass in the pipe line, — a rise of pressure occurs at its lower end, the governor of the turbine running under a constant load will be forced to somewhat reduce the amount of water entering the turbine; since the pressure rise, on account of the shutting, would have as a result an increased flow of water from the supply apparatus, therefore a larger amount of water supplied to the turbine; this would result in a speeding up of the turbine. The now following return wave will cause a drop in water pressure, the output of the turbine will be reduced, the governor will open and again close at the next pressure rise, and it can easily be seen that under these conditions the governor can increase the oscillations in the water column up to a certain maximum value.

Such experiences with air chambers have been had at many places and it is surprising that so far nothing about them has gained publicity.

The above investigation also shows that the oscillations will decrease the quicker, the larger the amount of water flowing through the pipe line, because the newly entering water, on account of its inertia, will counteract the oscillations and, therefore, is a very powerful factor in damping the water fluctuations.

This also explains the fact, which is very little known, that one can steady the governor which has become uneasy on account of water oscillations in the pipe line by opening a by-pass and giving the water in the pipe line a higher velocity. Experience also shows that simultaneous oscillations of the governor and of the water in the pipe line more readily happen when turbines utilize small quantities of water, viz., in cases where the velocity of the water in the pipe line is low.

In this respect standpipes, which have been frequently used in America, are better than air chambers. At a sudden complete or partial closing of the supply apparatus of the turbine (Fig. 5), the water level of the standpipe B will rise on account of the rise of pressure, and part of the water Q' will overflow the edge of the standpipe. The energy of oscillation, as a result, will be decreased in accordance with the ratio $\frac{Q'}{Q-Q'}$ if Q represents the

quantity of water flowing in the entire pipe line. The return wave must, therefore, be necessarily much smaller since the water at each following forward wave loses some of its energy on account of the water overflowing the edge of the standpipe. This circumstance, and the damping action of the water newly entering the pipe line, which changes energy of oscillation into eddies and friction, just as with air chambers, brings the oscillations very quickly to a stand-still, even if the speed governor has the tendency to increase same.

Similar to the standpipes act the safety valves; they must however, be sufficiently large to discharge at each oscillation a sufficient amount of water to cause a decrease of the energy of oscillation, notwithstanding the disturbing influence of the governor.

Also pressure-regulating devices have been provided which, in case of an increased pressure of the water, open a by-pass to the tail water; as, for instance, spring balanced accumulators, where the plunger, in case of rise of pressure, moves upward and opens a by-pass. Such devices are better than air chambers because they take energy out of the water, and also better than standpipes, because they do not contain a great mass.

An example of such a pressure-regulating apparatus, consisting of a spring balanced accumulator of large size and connecting with a by-pass valve, is shown on page 147, 1901, of *Schweizerische Bauzeitung*.

Any engineer who has to determine upon the dimensions of the pipe line is interested to know what increase in pressure will take place in the line if it is quickly closed, with a lower limit not to be exceeded, say two seconds, and if the water was flowing previously with maximum velocity corresponding to the turbines being totally open.

Increase of Pressure in a Pipe Line at Sudden Closing.

It shall first be investigated to what extent the pressure can rise in a pipe line if the latter is closed suddenly, so that the entire kinetic energy of the water flowing in the line has to be taken up by the elasticity of the pipe walls; viz., is used for doing work of deformation. If the pipes are

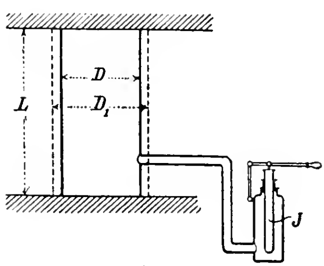


Fig. 6.

made sufficiently strong to withstand this increased pressure, one can do without any safety devices.

Suppose a cylinder of the diameter of D is clamped between two rigid plates of the unchangeable distance L, as shown in Fig. 6, and contains water under the specific pressure p. Now the contents J of a pump cylinder shall be pressed into the first cylinder, which results in increasing the pressure in the latter to p_1 and in enlarging the diameter into D_1. Apparently the annular volume must be

$$L\left(\frac{D_1^2\pi}{4} - \frac{D^2\pi}{4}\right) = J \qquad \text{II}$$

because incompressible fluid is assumed. The increase of pressure p_1 will largely depend upon whether the cylinder wall consists of elastic or unelastic material. Therefore the modulus of elasticity of the material of the wall is of prime importance. The specific strain K of the pipe walls is figured to $K = \frac{Dp}{2S}$, wherein S represents the thickness of the pipewalls, p the specific pressure, and D the pipe diameter. If by increasing the pressure the diameter D is enlarged into D_1, the circumference will be increased to the amount of a known quantity $D_1\pi - D\pi = (D_1 - D)\pi = \lambda$, and K will be increased to K_1, therefore giving $K_1 = \frac{D_1p_1}{2S}$. According to the law of elongation of a bar, the change of length of a bar is $\lambda = \frac{Pl}{fE}$, where P represents the increase in load, l the original length of the bar, f the sectional area of the bar, and E the modulus of elasticity. If one assumes now a cylinder strip of 1 in. height cut open and developed, which is under tension on account of the increased load $\frac{D_1p_1 - Dp}{2}$, wherein D is the original length of a bar, one finds

$$\lambda = D_1\pi - D\pi = \frac{(D_1p_1 - Dp)D\pi}{2\,SE} \qquad \text{III}$$

as first relation between D_1 and p_1, and by substituting $D_1p_1 - Dp = D_1(p_1 - p)$, which is permissible on account of the slight difference between D and D_1,

$$2(D_1 - D)ES = D_1D(p_1 - p). \qquad \text{IV}$$

Herewith is to be combined the previously developed equation II, according to which the known contents of the pump cylinder

J must be equal to the larger cylinder volume less the original volume.

By pressing down the pump plunger, a certain amount of work, A, is performed, which, if for simplicity's sake a linear rise of pressure in the cylinder is assumed, is expressed by $f \times \frac{p_1 + p}{2} \times h = A$; and since $J = f \times h$ = the area of the pump plunger multiplied by the stroke, it follows $J \times \frac{p_1 + p_2}{2} = A$. This amount of work has been taken up by the walls of the cylinder as work of deformation. Suppose that the same deformation would take place if the amount of work A was conveyed to the water, not by a pump, but by suddenly changing kinetic energy contained in the water into potential energy, viz., pressure, — as it happens if a pipe line is suddenly closed, — the rise of pressure in a pipe line at sudden closure can be calculated.

If a horizontal pipe line in which water flows with a velocity v is closed suddenly, the amount of energy $A = \frac{FL \times \gamma}{g} \times \frac{v^2}{2}$ is used for dilatation of the pipe line if the length of the line is considered unchangeable. If the rise of pressure would occur evenly in the entire length of the pipe line, it could be calculated from the formulæ

$$A = \frac{J(p_1 + p)}{2} = \frac{L\pi(D_1^2 - D^2)}{4} \times \frac{p_1 + p}{2} = \frac{Lf\gamma}{g} \times \frac{v^2}{2} \qquad \text{V}$$

and

$$p_1 = \frac{D_1 - D}{2D_1 D} ES + p, \qquad \text{IVa}$$

one would need only to eliminate D_1 to obtain an equation for p_1.

The rise of pressure, however, does not take place uniformly, but will be greatest at the lower closing gate of the line, and will decrease towards the point of entrance. Therefore, the dilatation of the pipe line will be greater at the lower end, and at the entrance point of the water there will be none whatsoever.

The volume, which in the scheme drawing Fig. 6 corresponds to the amount of water pressed into the cylinder by the pump, will approximately take a shape as indicated in Fig. 7 by cross lines, viz., consist of a frustum of a cone less the contents of a cylinder, if linear increase of pressure is assumed.

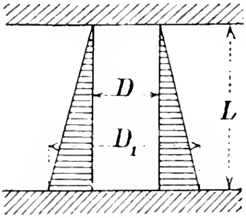


FIG. 7.

Therefore, we have now, instead of II, the equation:

$$J = \frac{1}{12}\pi L(D_1^2 + D_1 D + D^2) - \frac{\pi}{4} L D^2, \qquad \text{VI}$$

and

$$A = \frac{1}{12}\pi L(D_1^2 - D_1 D - 2D^2)\frac{p_1 + p}{2} = \frac{LF\gamma}{g} \times \frac{v^2}{2}, \qquad \text{VII}$$

which, with equation IV, permit of a calculation of p_1.

Horizontal pipe lines, however, do not occur with turbine plants. If the line is inclined, there will, at its end, exist a pressure which is equal to the head H less the velocity head $\frac{v^2}{2g}$. With flowing water, therefore, the distribution of pressure will be such as shown in the scheme drawing Fig. 7 by the cross-lined part.

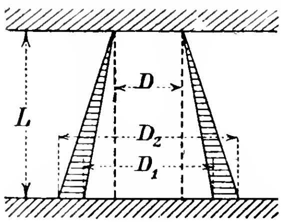


FIG. 8.

If, however, sudden closing takes place, the increase in pressure will be practically distributed, as shown in Fig. 8 by the cross-lined area, which is equal to the volume of the difference of two frusta of cones which on top have the diameter D (pipe with no pressure) and at the bottom the diameters D_1 and D_2. In this case, J, the increased volume, is the difference of the volume of the two frusta of cones, and one finds:

$$A = \frac{p_1 + p}{24}\pi L\,[(D_2^2 + D_2 D + D^2) - (D_1^2 + D_1 D + D^2)] = \frac{LF\gamma}{g} \times \frac{v^2}{2},$$

which is expressed more shortly,

$$L\pi\frac{p_1 + p}{12}(D_2^2 - D_1^2 + D_2 D - D_1 D) = \frac{FL\gamma}{g} \times v^2. \qquad \text{VIII}$$

D_1 has to be calculated from the prevailing head, deducting the friction head, and the formula takes the shape:

$$\pi(D_1 - D) = \lambda = \frac{D p_1 D \pi}{2SE};$$

or, if the heads corresponding with the pressures p and p_1 are designated by h and h_1 ($p = \gamma h$), where

$$h_1 = h \frac{v^2}{2g},$$

$$D_1 = D\left(1 + \frac{\gamma h_1 D}{2SE}\right). \qquad \text{IX}$$

From equation VIII, and from the equation resulting from the law of the extension of a bar,

$$2(D_2 - D_1)ES = D_1^2(p_2 - p_1), \qquad \text{X}$$

wherein was made $D=D_1$, one can, by eliminating D_1, calculate the pressure p_2. An exact determination will be difficult, because the expressions become very complicated. By the following procedure one finds a simple formula for the increase in pressure.

If one makes $D_2D=D_1^2$, since $D_2>D_1>D$, and all three quantities differ from each other a small amount only, equation VIII will read:

$$\frac{\pi L}{12}(D_2^2-D_1D)(p_1+p)=\frac{FL\gamma}{g}v^2.$$

If one further introduces for F the value $\frac{D_1^2\pi}{4}$; further for D_1D, once D_1^2 and once D^2; the correct result must be between the two results obtained by this last approximation; then follows:

$$\frac{1}{3}(D_2^2-D_1^2)(p_2+p_1)=\frac{D_1^2\gamma v^2}{g};$$

or,

$$(D_2+D_1)(D_2-D_1)(p_2+p_1)=3\frac{D_1^2v^2}{g}.$$

By dividing this equation by equation X, the critical value (D_2-D_1) is eliminated and one obtains the quotient

$$\frac{(D_2+D_1)(p_2+p_1)}{2ES}=\frac{3D_1^2\gamma v^2}{g(p_2-p_1)D_1^2};$$

further:

$$(p_2^2-p_1^2)=6\frac{S}{D_2+D_1}\frac{E\gamma v^2}{g}.$$

Since the differences between D, D_1 and D_2 amount to small fractions of an inch only in most cases, one can make $D_1+D_2=2D$, and the relation is:

$$p_2^2=p_1^2+3\frac{S}{D}\frac{E\gamma v^2}{g}.$$

Making $h_1=\frac{p_1}{\gamma}$, and $h_0=\frac{p_2}{\gamma}$, in which h_1 and h_0 represent the heads corresponding with the pressures p_1 and p_2, it follows:

$$h_0^2=h_1^2+\frac{3S}{D}\frac{Ev^2}{\gamma g} \qquad \text{XI}$$

and the increase in pressure

$$(h_0)=h_0-h_1=\sqrt{h_1^2+\frac{3S}{D}\frac{Ev^2}{\gamma g}}-h_1.$$

Herein h_0 and h_1 are to be expressed in feet of water, S and D in units of length, g and v in feet, $\gamma=62.408$, and E in pounds per square foot.

Example.

In a pipe line of 54 in. diameter, water flows with a velocity $v=6$ ft.; the lowest pipes of sheet steel are $\frac{3}{4}$ in. thick; the line is under a head of 200 ft. or a pressure of 86.8 lb. per sq. in. To what point will the pressure rise if the flow is stopped suddenly?

According to formula XI is

$$h_2^2 = 200^2 + 3\frac{0.75}{54} \times \frac{28\,000\,000 \times 144 \times 36}{62.4 \times 32.153}$$

$$= 40\,000 + \frac{2.25}{54} \times \frac{4\,032\,000\,000 \times 36}{108\,342.9} = 40\,000 + 3\,013\,432$$

$$= 3\,053\,432$$

$$h_2 = \sqrt{3\,053\,432} = 1\,747$$

$$(h_0) = 1\,747 - 200 = 1\,547 \text{ ft.}$$

The rise of pressure at the assumed, but in reality impossible, sudden closure will be over 1 500 ft., more than seven times p_1. The pipes would be strained

$$k = \frac{D}{2} \times \frac{p}{S} = 27 \times \frac{672}{0.75} = 24\,192 \text{ lb. per sq. in.,}$$

which would exceed the elastic limit, but still leaves some safety against rupture. The normal strain of the pipe is:

$$k = \frac{D}{2} \times \frac{p}{S} = 27 \times \frac{86.8}{0.75} = \frac{2\,343.6}{0.75} = 3\,124 \text{ lb. per sq. in.}$$

If the pipe was only $\frac{3}{8}$ in. thick it would be normally strained 6 248 lb. to the sq. in. At sudden closure the increase in pressure, however, would be less than with thick walls, because the thinner walls can give more.

For $S = \frac{3}{8}$ in.;

$$h_2 = \sqrt{40\,000 + \frac{1.125}{54} \times \frac{4\,032\,000\,000 \times 36}{2\,006.35}}$$

$$= \sqrt{40\,000 + 1\,506\,716}$$

$$= \sqrt{1\,546\,716} = 1\,243,$$

which is less than seven times h_1; there is further,

$$k = 27 \times \frac{540}{0.375} = 38\,880,$$

not twice the value of 24 192 found above, as was to be expected with walls of half the thickness.

The formula does not contain the length of the pipe line, which is quite evident; for each foot of length of the energy-carrying water there is a foot of length of energy-receiving pipe wall. This, of course, is correct only with the assumed sudden closure. It will be found in the following what tremendous influence the length of the line has upon the rise of pressure if

the closure takes place in a certain determined time, say 2 to 6 seconds; of course the values will be found smaller than with sudden closure.

Since in formula IV the velocity v for turbine pipes will always have a maximum between 6 and 9 ft., the modulus of elasticity E for plate steel has a constant value, γ and g also are fixed values, the increase in pressure at sudden closure depends only upon the ratio between the thickness of the pipe and its diameter and upon the pressure to which the pipes are subjected. The example which was figured out above shows that under high heads an absolute safety at sudden closure can be obtained only by extraordinarily increasing the thickness of the pipe, which would considerably increase the cost of the line. It is therefore natural that with long pipe lines one introduces safety devices which at sudden closure prevent its rupture. Of course one finds occasionally such safety devices where there is not the least danger for the pipe line. Such needless installations could happen only because on the subject treated herewith nothing has been furnished anywhere in the technical literature that is useful to the practicing engineer.

The energy taken up by the pipe walls is not destroyed, but the pipe walls will, after stationary conditions are reached again, contract to their original diameter and force back the surplus, but very small, quantity of water into the reservoir, which may be accompanied by some fluctuations back and forth. These conditions will be treated with the discussion of the standpipes.

Increase of Pressure with Definite Time of Closure.

The closure of a line can never take place instantaneously; a certain time for moving the closing mechanism will always be required, which might sometimes be very short.

It is to be investigated what rise of pressure will take place at the lower end of a turbine line, if the governor closes the turbine within a certain time, called Closing Time, designated T.

Apparently in this case a moving column of water, whose length is always equal to the length of the pipe line, is first retarded in its motion by increasing the resistances at the section of the discharge and finally stopped entirely. Herewith this column of water causes a shock against the closing apparatus, which is felt in the fluid as an increase in pressure, and, on account of the incompressibility of the water, is transmitted backwards towards the entrance section with decreasing intensity. For determining

approximately the greatest increase in pressure, it is sufficient to apply the law of impact, in which the energy contained in the water during the discharge is not deducted, however. It may also be mentioned again that the problem dealt with is a problem of undulation, as is evident from the previous discussions.

According to the law of impact $\int pdt = \int Mdv$, the quantity of water in the pipe line, $M = \frac{LF\gamma}{g}$, is given by the length L, and the area F of the pipe line by the specific gravity γ of the water and by the acceleration of gravity g. The force of impact p depends upon the time within which the closure takes place; it is zero at the beginning of the closure, grows with the increasing closure and probably reaches its maximum at the moment of closure. The increase of the force of impact with the time t can take place according to the curves, I, II, III, in Fig. 9.

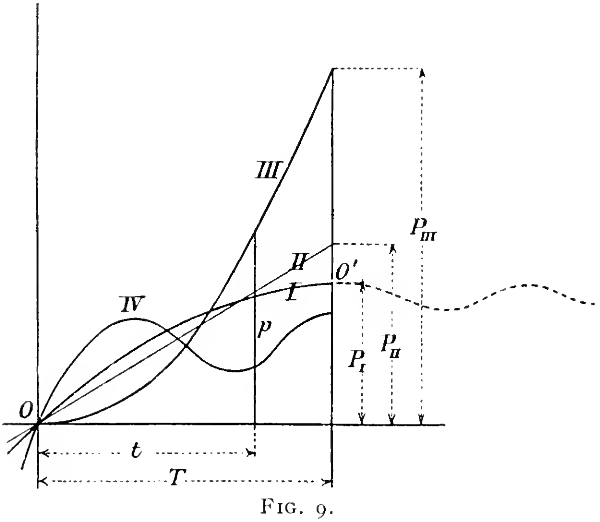


FIG. 9.

Suppose the increase in pressure takes place in direct proportion with the time, according to curve II in Fig. 9; then follows $\frac{p}{P} = \frac{t}{T}$, or $p = P\frac{t}{T}$, where P is the maximum force of impulse at the moment of complete closure. Entering this into the above integral equation gives:

$$\frac{P}{T}\int_{t=0}^{t=T} tdt = Mv; \text{ or, solved, } T = 2\frac{Mv}{p};$$

or,

$$P = 2\frac{Mv}{T} = 2\frac{LF\gamma v}{gT}.$$

Dividing this equation by the area F gives the force of impact per unit of area; and as it is customary to express the pressure in feet of water column (h), and $\gamma h=$ pressure per unit of area, the rise of pressure at the moment of close is $(h)=2\frac{Lv}{gT}$, and the total pressure

$$h_2 = h_1 + \frac{2Lv}{gT}, \tag{XII}$$

where h_1 represents the pressure before the closing began. In this equation the rise of pressure appears dependent directly upon the length of the pipe line.

If the rise of pressure took place with the time according to curve III in Fig. 9, for instance, in accordance with the relation $p=P\frac{t^2}{T^2}$, curve III being a parabola with its vertex in O and with vertical axis, the calculation would give:

$$\frac{P}{T^2}\int_{t=o}^{t=T} t^2dt = Mdv;\ P = \frac{3Mv}{T} = 3\frac{LF\gamma v}{gT};$$

$$(h) = 3\frac{Lv}{gT};\ h_2 = h_1 + 3\frac{Lv}{gT}. \tag{XIII}$$

The rise of pressure would be 50 per cent. greater.

Suppose p was dependent upon t, according to curve I as a parabola, with its vertex in O_1, the calculation gives:

$$P = \frac{3}{2}\frac{LF\gamma v}{gT};\ (h) = \frac{3}{2}\frac{Lv}{gT};$$

$$h_2 = h_1 + \frac{3}{2}\frac{Lv}{gT}. \tag{XIV}$$

Of the formulas XII, XIII and XIV, probably XIV is the most correct one, as it permits a continuation as a sinoidal line, according to the following vibrations of pressure, as indicated in Fig. 9. Through the influence of the elasticity of the pipe walls, however, the actual rise of pressure should be less than theoretically determined, about $h=\frac{Lv_1}{gT}$, which expression is occasionally used for calculating the rise of pressure. From the somewhat limited experience of the writer, however, formula XII gives values which agree with experiments.

Prof. A. Rateau (Paris), after analytic treatment in which, however, the influence of the dilatation of the pipe upon the rise of pressure is not considered, arrives at the expression

$$\frac{h_2}{h_1} = \frac{2+n}{2-n}, \text{ wherein } n = \frac{Lv}{gTh_1}.$$

Very completely, and with consideration of the elasticity of the pipe walls, and also of the compressibility of the water, the question of the hydraulic ram has been treated by M. L. Allievi. According to Allievi, if the time of closure exceeds a certain amount, which depends upon the length of the line and upon the velocity of transmission of the pressure vibrations in the column of water, the maximum rise of pressure takes place during the closure, drops then, and finally, towards the end of closing, rises again, as indicated in curve *IV* in Fig. 9. If the time of closure is long enough, several vibrations may occur within one period of closure. The maximum pressures are found somewhat smaller than according to Rateau, which must be expected since the latter neglects the dilatation of the pipe.

Example.

A pipe line 1 800 ft. long, of a diameter of 54 in., in which the water flows with a velocity of 6 ft., shall be closed in 4 seconds; the fall is 200 ft., so that the bottom pipes are under a pressure of 86.8 lb. We use formula XIV.

The maximum pressure at the end of closure is:

$$h_2 = 200 + \frac{3}{2} \frac{1\,800 \times 6}{2 \times 32.153 \times 4} = 200 + 62.979 = 263 \text{ ft.}$$

The increase in pressure amounts, therefore, to 63 ft., or $27\frac{3}{4}$ lb., and this result was found at an experiment, which was, however, unintentional.

The formula of Rateau gives in this case first

$$n = \frac{1\,800 \times 6}{4 \times 32.153 \times 200} = 0.42$$

and

$$h_2 = 200 \times \frac{2.42}{1.58} = 200 \times 1.532 = 306.4 \text{ ft.},$$

corresponding with an increase of head of 106.4 ft., or 46.18 lb., which fairly agrees.

The results found so far afford an insight into the construction of an empiric formula which gives the maximum rise of pressure at the end of a pipe line at closure within a certain time with a given initial pressure and under consideration of the elasticity of the pipe walls.

It is evident the rise of pressure must be less with increasing time of closure and have an asymptotic course with relation to the axis of time, since with an infinitely long time of closure there would be no rise of pressure. For $T = 0$, the final pressure must

have the value found in formula XI and the corresponding rise of pressure (h_0) is shown in Fig. 10 by the ordinate AO. The course of the curve is probably fairly correctly shown by the line AB, which can be substituted by one leg of a symmetric hyperbola, whose parameters are NN' and BN. Then $(h)(T+U)$ is a constant and also $(h_0)U$ a constant. If two relative values, for instance, (h_2) and T_2, are known, a further point of the curve is determined, for which $(h_2)(T_2+U)$ is constant.

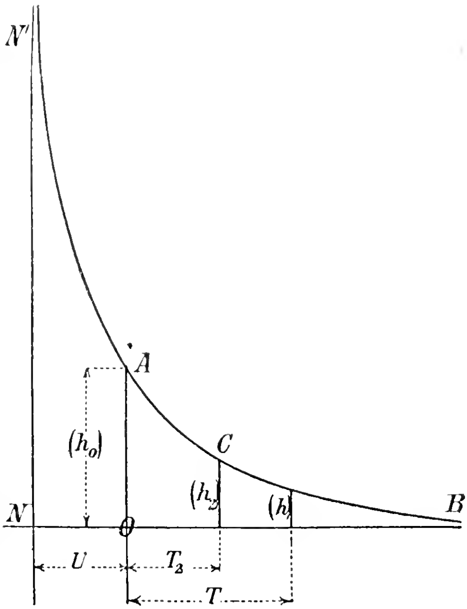


FIG. 10.

By eliminating the constant from the above three equations one finally finds for the maximum rise for a certain time of closure T,

$$(h) = \frac{(h_0)}{\frac{h_0 - h_2}{(h_2)}\,\frac{T}{T_2} + 1} \qquad \text{XV}$$

and finally,

$$(h) = \frac{\sqrt{h_1{}^2 + 3\frac{S}{D}\frac{Fv^2}{\gamma g}} - h_1}{\frac{T}{T_2(h_2)}\sqrt{\left(h_1{}^2 + 3\frac{S}{D}\frac{Fv^2}{\gamma g}\right)} + 1 - \frac{h_2}{(h_2)}\,\frac{T}{T_2}} \qquad \text{XVI}$$

where h represents the pressure prevailing at the beginning of the closure.

Introducing the values calculated in the previous examples by formulas XI and XIII, and for the latter the value of $h_0 = 1\ 747$, confirmed by experiment, $h_2 = 263$, $T_2 = 4$ seconds, gives for a fall of $h_1 = 200$ ft. and for a pipe line 1 800 ft. long, the formula

$$(h) = \frac{1\ 547}{\frac{1\ 747 - 263}{63 \times 4}\,T + 1} = \frac{1\ 547}{5.888T + 1} = \frac{1}{0.0038\,T + 0.00064}$$

which gives for a time of closure of 2 seconds, $(h) = 121.3$, and for $T = 10$ seconds, $(h) = 25.9$.

The reducing influence of the yielding pipe walls is apparently more evident with shorter closing time.

Upon the question where the potential energy of the flowing water goes, one can reply that part of same reaches with the water with increased pressure the tailwater through the nozzle. The part transformed into pressure, viz., the resulting rise in pressure, does not remain passive. The pipes dilated by same gradually contract again and force the surplus of contents upwards, whereby on account of the kinetic energy of the water flowing opposite to the water entering the pipe, after some time a drop of pressure takes place at the lower end of the pipe; hereupon follows again a downflow and a somewhat smaller rise of pressure. And so the water in the pipe line oscillates for considerable time (frequently half an hour) up and down, until the pipe friction and the friction of the particles of water between themselves have destroyed the remaining amount of energy. Therefore, by sudden closure, an impulse for vibrations of the water in the pipe line is always given.

If the line is closed by the turbine governor not entirely but partially, a smaller rise of pressure takes place, which also can be calculated from formula XIII if for T that time is substituted that was necessary for partially closing the gate. In this case, however, the governor remains in action and helps considerably not to let the aforesaid vibrations come to rest, since it always closes when a pressure rise takes place, thereby still more raising the pressure, and always opens when the pressure falls in the line, whereupon the drop in pressure continues, etc. The vibrations of the water increase to a maximum and then remain constant. It may be mentioned that sometimes the entire pipe line takes part in these vibrations and even leaves its supports at points of change in direction; the writer had occasion to observe such occurrences.

The results calculated from formulas XII to XVI do not offer any guarantee, especially not if a longer closing time was figured upon, that the calculated rise of pressure might not be exceeded on account of the just-mentioned unfavorable influence of the governor. One has to deal with enforced fluctuations of the water in the pipe line, and the rising or falling pressure in the pipe line can, in very unfavorable cases, reach very high values on account of resonance of the vibrations.

An analytical treatment of these occurrences would be of theoretical interest only and hardly furnish results applicable in practice; in those cases, namely, where vibrations in the pipe line

are, in fact, caused by the governor, one is compelled to put the governor out of service unless one succeeds in stopping this condition by opening a by-pass or by other means, viz., changing the closing time, raising the degree of unsteadiness. The relation of these factors, to which secondary points are connected, that are beyond any calculation, is so complicated that it is impossible to expect the engineer, who has to start up the governor, to calculate and check up these vibrations.

The possibility of an occurrence of high pressures, however, under the conditions of service just mentioned, makes it seem advisable to dimension the pipe line in such cases sufficiently liberally to withstand even at sudden closure the rise of pressure occurring with a factor of safety of $2\frac{1}{2}$.

Standpipes, Free-Air Pipes.

The arrangement of standpipes can be such that the upper, sometimes flaring, edge is level with the water surface in the reservoir, so that, at a slight pressure rise, overflowing of the water over the upper edge of the pipe takes place. Or the standpipe can be higher, so that the overflow only takes place at a considerable increase in pressure. Both arrangements have been installed, the latter especially, where it was difficult to carry away the overflowing water.

One would think that standpipes, especially if installed at the lower end of the pipe line, would be capable of affording absolute safety against bursting of pipes. This, however, is not so, since at sudden closure part of the energy of the water flowing in the pipe line has to be used to accelerate the water in the standpipe. A resting body of water of such considerable volume requires for its setting in motion a fair amount of energy, and can in no case be suddenly brought from rest to a certain velocity. Therefrom results that also with standpipes considerable rise of pressure will occur at the lower end of pipe lines, and it only depends upon the ratio between the length of the pipe line and the height of the standpipe and upon the ratio between the thickness and the diameter of the pipe whether at all a standpipe affords an effective protection to the pipe line.

The pressure rises occurring with standpipes at the lower end of pipe lines at sudden closure of the line will now be investigated and calculated. A standpipe of the second type mentioned shall be assumed, whose height is such that an overflow over the upper edge of the pipe cannot take place even with the greatest occurring pressure rise.

First the simple case will be treated, where the velocity of flow in the pipe line is so great that the flow and discharge take place with a velocity due to the entire head, so that, if the water flows through the line with the velocity $v = \sqrt{2gh}$, the level of the water in the standpipe is very low, as shown in Fig. 11, and the amount of water contained therein can be neglected.

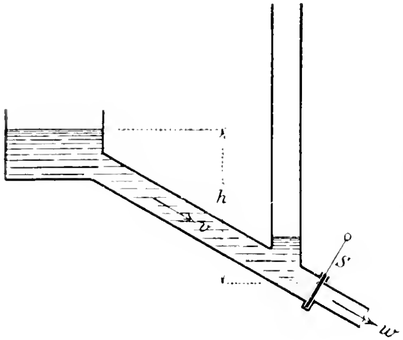


FIG. 11.

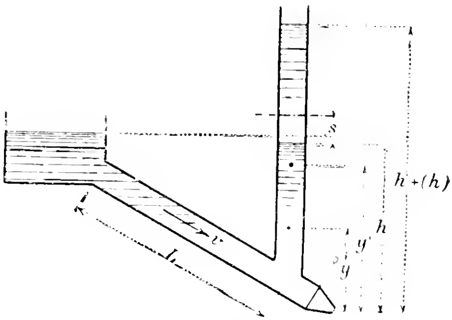


FIG. 12.

At sudden closure of the pipe line — for instance by the gate S — the water will first rise to the level h on account of the hydrostatic pressure; then, however, on account of the energy of the water stopped in its flow, beyond this, up to $h + (h)$. (Fig. 12.)

Suppose that for this additional rise (h), the entire kinetic energy acts, viz., the amount $A = \frac{FL\gamma}{g} = \frac{v^2}{2}$, the volume of lifted water $F(h)\gamma$ multiplied with the path of the center of gravity S, viz., $\frac{(h)}{2}$, will represent the work performed and it can be made $\frac{FL\gamma}{g}\frac{v^2}{2} = F(h)\gamma\frac{(h)}{2}$, which is expressed more simply, considering that $v = \sqrt{2gh}$,

$$Lh = \frac{(h)^2}{2};$$

or,

$$(H) = \sqrt{2Lh}. \qquad \text{XVII}$$

The maximum pressure occurring will, therefore, be

$$h + (h) = h + \sqrt{2Lh} = h + v\sqrt{\frac{L}{g}}.$$

The increase in pressure is, as has to be expected, the greater the longer the pipe line is and the more rapidly the water flows therein; therefore it also depends upon the head h, proportional to its root, however.

With turbine pipe lines the area of discharge from the nozzle is always considerably smaller than the area of the pipe line; therefore, the velocity of flow v in the pipe line is considerably smaller than $\sqrt{2gh}$.

If the area of discharge is designated by f and the velocity of discharge by w, on account of the law of continuity, $vF=fw$, therefrom with given areas and known velocity of the discharge of the water from the turbine gate, the velocity v of the water in the pipe line can always be easily found.

If the turbine gate is closed suddenly, an impact of the moving body of water of the mass $\frac{LF\gamma}{g}=M^1$ against the mass of water stationary in the standpipe $M''=\frac{hF\gamma}{g}$ takes place and the latter will be set in an upward motion up to a certain height (h), which will be reached after T seconds. In this case, also considering the dilatation of the pipe, which takes place during a short period after the impact and then disappears again, the energy of the flowing water is used exclusively to lift the entire column of water in the standpipe.

If y (Fig. 12) indicates the height of the center of gravity of the water column above the opening of discharge, and y' the position of the center of gravity after the water column reached its highest position, therefore $y'-y$ the rise of the center of gravity, then $y'\frac{h+(h)}{g}F\gamma-y\frac{h}{g}F\gamma$ is the work performed, which, on the other hand, must equal the kinetic energy of the water, so that one can say:

$$y'\frac{F\gamma}{g}[h+(h)]-y\frac{h}{g}F\gamma=\frac{LF\gamma}{g}=\frac{v^2}{2};$$

and since

$$y=\frac{h}{2} \text{ and } y'=\frac{h+(h)}{2},$$

it follows that

$$\tfrac{1}{2}[h+(h)]^2-\frac{h^2}{2}=L\frac{v^2}{2};$$

or,

$$2(h)h+(h)^2=Lv^2. \qquad \text{XVIII}$$

From this equation (h) can be calculated. The calculated value, however, will always be greater than the actually occurring rise in pressure (h), since part of the kinetic energy is used up in forming eddies and transformed into heat.

Solving the squared equation, XVIII gives

$$(h) = \sqrt{h^2 + Lv} - h.$$

Approximately also the time can be calculated after which this rise in pressure will be reached.

If the moving mass of water M^1 strikes the stationary mass of water M'', a deformation of the pipes must occur (since the water is assumed to be incompressible) which takes up the energy $\frac{M^1 v^2}{2}$; while this dilatation takes place the motion of the mass M'' already commences, and when the dilatation after a very short period of time reaches its maximum value, the two masses of water move with the joint velocity v, which can be calculated as impact of unelastic bodies from the formula $v_1 = \frac{M^1 v}{M^1 + M''}$. This is the velocity the water in the pipe line and in the standpipe has after the impact. Now, however, the column of water in the standpipe rises; this causes a counter-force which retards the motion. At the same time the pipes gradually contract again and transfer the previously received energy again to the water. Finally, when the motion of the water reaches its end the previously calculated maximum value of the rise (h) will be reached.

For the motion to be considered here the differential equation, well known from dynamics, stands $\frac{d^2 s}{dt^2} = -q$, where q represents the retardation of the water flowing in the pipe line. The counteracting force is the weight of the body of water rising above the original level in the standpipe. This counterforce is directly proportional to the rise; therefore can be expressed by $K = \text{Const.} \times s$. For $s = (h), K = F(h)\gamma$; therefore $\text{Const.} = F$ and $K = F\gamma s$.

The acceleration is given by the ratio of force to mass; therefore

$$q = \frac{F\gamma s}{M^1 + M''} = \frac{F\gamma s}{\frac{F\gamma L}{g} + \frac{F\gamma h}{g}} = \frac{sg}{L+H}.$$

Accordingly, the above differential equation becomes

$$\frac{d^2 s}{dt^2} - \frac{sg}{L+h} = 0.$$

The latter equation is the one of the sinoidal curve. Making $\sqrt{\frac{g}{L+h}} = a$, the general integral is

$$s = A \cos a\, t - B \sin a\, t,$$

wherein $A = (h) \sin\beta$ and $B = (h) \cos\beta$, and β represents the phase of the vibration.

Since in the considered case the phase change disappears, since time is counted from the passing of the center position, $\beta = 0$, $A = 0$ and $B = (h)$, therefore

$$s = (h) \sin \sqrt{\frac{g}{L+h}} \times t;$$

for $s = (h)$, $t = T$; thus

$$(H) = \sqrt{\frac{g}{L+h}} \times T,$$

and

$$\sqrt{\frac{g}{L+h}} \times T = \text{arc} \sin 1 = \frac{\pi}{2};$$

or, finally,

$$T = \frac{\pi}{2}\sqrt{\frac{L+h}{g}}.$$

This shows that the maximum value of the calculable pressure rise at the end of the line will occur the later, the longer the line and the higher the standpipe. But it may be mentioned again, that, on account of the compressibility of the water and of the consequent velocity of travel of the pressure in the water, considerable deviations from the above results of calculation have to be expected, especially if the line is very long.

After having reached the highest position the water in the standpipe will drop again, and the entire mass of water will adopt a velocity opposite to the one previously had, which reaches its maximum at the moment the original level h is reached, but afterwards decreases again. Hereby the water is forced back into the reservoir, the level of water in the standpipe sinks to the amount s below the level h. Now again begins the flow of the water in the original direction, rise beyond the level h, and so forth.

Sinoidal vibrations of the water take place which, on account of several damping factors, amongst which the friction of the water against the pipe walls, gradually come to rest.

If the standpipe is of such shape that the water can overflow when it rises, the time T, after which the maximum pressure rise occurs, and the amount of the latter, change only inconsiderably, both becoming smaller. The only considerable influence the overflowing of the water has is upon the back vibration of the water, which is practically of no importance, since the mass of water has been reduced on account of the overflow. The back vibrations, therefore, become smaller, but the strain of the pipes

at the lower end of the line will be the same when the gate is closed as if no overflow of the water takes place.

Air Chambers.

From the preceding discussions of standpipes the action of air chambers may be immediately considered.

They act principally upon the pressure conditions of a pipe line like standpipes with which an overflow of the water does not take place and which are so short that the mass of the water contained therein, M'', need not be considered. The analytical investigation of the pressure conditions at sudden and rapid closure can be simplified by introducing the volume of the air chamber as a cylinder of the area of the pipe line and a height L_1, which can be brought into a simple relation to the length of the pipe line.

For the changes in pressure and volume of the air, the Mariotte Law can be applied with quite sufficient approximation.

After a rapid or sudden closure the energy of the flowing water will principally compress the air contained in the air chamber. If the maximum pressure in the air chamber is reached, which always will take place a considerable time after closing the gate, the air expands again and forces the water contained in the air chamber back into the pipe line; then follows again a pressure rise and so forth, since here the impulses of vibration are nearly the same as with standpipes. But as the mass of water is smaller than with a standpipe, the vibrations will take place at shorter intervals; the maximum value of the pressure rise will be the same as with standpipes.

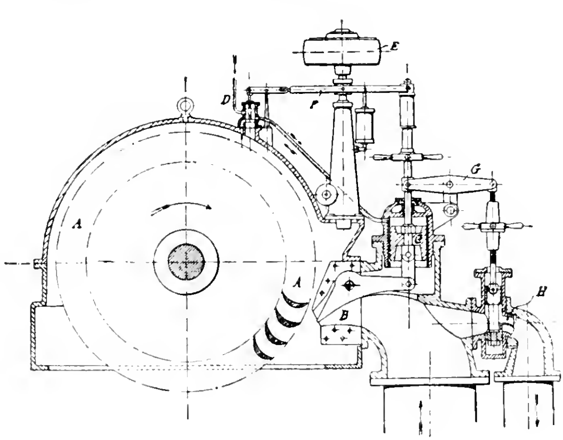


Fig. 13.

Air chambers are no more used to-day, so that a further investigation of the occurrences connected therewith can be dispensed with.

By-Passes (Synchronous Gates).

A clear illustration of a synchronous gate is given in Fig. 13, which shows an impulse wheel built by the firm of Messrs. Riva, Monneret & Co., of Milan, for the electric central station of the power transmission plant Villadossola-Intra.

The impulse wheel *A*, cast of steel, takes water from a single nozzle *B*, whose area of discharge can be reduced by means of a tongue with bell-crank. The bell-crank is connected by a link with a piston *C*, which is always pressed upward, if the space above the piston communicates with the atmosphere. If, however, pressure water enters this space, the water pressure acting upon the tongue opens the water inlet. The admission of the pressure water takes place through the balanced piston valve *D*, which is operated by a Hartung governor. In customary manner over-regulation is avoided by the floating lever *F*, moving back the valve *D*. From the piston rod a horizontal lever *G* branches off, which, by means of a link, operates the synchronous gate *H*, and this in such a way that with the tongue closed the entire maximum area of the nozzle is open in the synchronous gate. With the nozzle entirely open, however, the gate *H* is fully closed. Therefore, to the water in the pipe line the same discharge area is offered all the time, and a pressure rise or drop cannot take place in the pipe line with a change of nozzle opening. The discharge from the gate into the tailrace must be directed through a damping apparatus, which, as much as possible, destroys the energy of the discharge water; otherwise the issuing jet of water could easily destroy the masonry of the tailrace.

Synchronous gates of such arrangement, however, have the disadvantage that a maximum quantity of water is always used, not considering whether the turbine runs under full load or almost at no load. A storage of the water in the intake is impossible with this arrangement. Therefore, where storage basins are provided, and at times water has to be saved as much as possible, such synchronous gates cannot be applied, or have to be shut down when water is short.

In those cases, where the available quantity of water is sometimes less than the turbine can consume at full opening, the valve of the synchronous gate must be made adjustable, so that

with the nozzle of the turbine fully closed it only opens in accordance with the available quantity of water. This arrangement offers no constructive difficulties, but no fargoing economy of water can be obtained with it. In Fig. 13, the handwheel *K* is for this adjustment.

There are, however, also devices where the synchronous gate opens quickly at rapid closure of the nozzle, thus avoiding any pressure rise in the line, but then closes slowly, so that the dis-

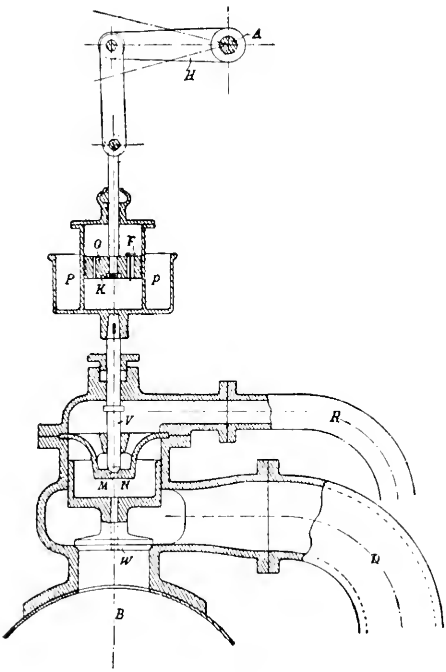


FIG. 14.

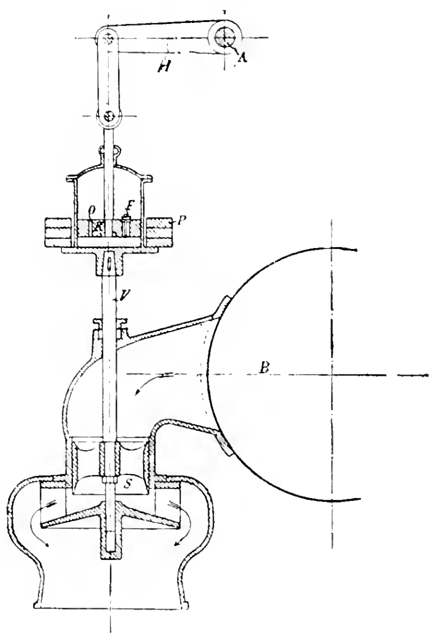


FIG. 15.

charge of water through the by-pass takes place only during a short adjustable period. Of the many possible designs solving this problem, the two illustrated in Figs. 14 and 15 may be mentioned.

In Fig. 14, the lever *H* is connected with the governor shaft *A* in such a way that with the closing motion of the shaft the left end of the lever rises. Hereby an oil cataract is lifted, since the oil above the piston *K* of the cataract cannot quickly enough flow down through a small opening *O* in the piston. In the bottom of the cataract a valve pin *V* is inserted, which closes an opening *M* in the upper cover of the discharge casing, through

which water flows from the chamber *N* through the pipe *R* into the tailrace. If this opening is uncovered by lifting the cataract, the pressure drops in the chamber *N* above the valve piston, and the latter, lifted by the pressure of the water upon the valve *W*, moves upward, hereby lifting the valve *W*, so that through the same, water can flow from the pipe line *B* through the curved pipe *D* into the tailrace.

When the lever *H* stops, the cataract slowly sinks. The velocity of this downward motion can be regulated at will by changing the opening in the cataract piston or by dropping weights into the cup-shaped extension *P* of the cataract, and finally the valve pin *V* again closes the opening *M*. Through a bore in the valve plunger, water enters the chamber *N*, whereupon soon the pressure in the pipe line is established in *N* and the valve *W* is forced downward and finally closed, since the diameter of the plunger is larger than that of the valve. At the downward motion of the lever *H*, the small valve *F* in the cataract piston comes into action, which permits the cataract fluid to flow quickly from below the piston above the same.

Less clever but simpler and, therefore, less subjected to various disturbing incidents, is the device shown in Fig. 15. As in Fig. 14, from the pipe line *B* a fitting branches off which terminates in a piston valve chest. The governor shaft *A* acts by means of the lever *H* upon the piston *K* of an oil cataract, which is rigidly fastened to the other end of the piston rod *V* of the piston valve *S*. The piston *K* has one or several holes *O*, and a valve *F*, which permit an easy drop of the piston when the piston valve is completely closed. The action of this device is analogous to the one described in Fig. 14, and, therefore, requires no further explanation. Weights *P* insure the drop of the piston into the closed position, which takes place the quicker the more weights are added. The piston of the oil cataract must be at least of such area as corresponds with the resistance against its upward motion plus the loaded cataract casing under the most unfavorable circumstances.

One would think that by installing such quick-opening and slow-closing devices the desired result was reached, viz., the pipe line protected against excessive strains, best possible economy of water guaranteed and the action of the governor improved by maintaining as much as possible constant pressure in the pipe line. In all three directions mentioned, however, cataract devices are imperfect in their performance.

So far only the pressure rise at rapid closing of a pipe line

has been taken into consideration. But with rapid opening of the supply pipe a considerable drop of pressure occurs in the pipe line, which unfavorably influences the action of the governor. The entire mass of water in the pipe line has, with an increased load on the turbine, to be accelerated from a velocity v_1, to a higher velocity v_2, and this cannot occur suddenly, but a certain time is required. However perfect the turbine governor might be, by opening the supply apparatus instantly at a drop of speed, in the first moment no greater quantity of water will pass through the turbine and only gradually the water will be accelerated to the required velocity. In the meantime, however, the governor has opened the supply apparatus much further than necessary and must close again, viz., it has worked too far. At the following closure the by-pass will be opened and a quantity of the valuable water flows needlessly into the tailrace, for there is no danger for the pipe line. Standpipes near the power house can be of favorable influence, since they supply ample water to the turbine in case of a sudden drop in pressure.

In plants where the load of the turbine is changing frequently and considerably, the loss of water at both closing and opening can become so great that it may nearly reach the one caused by a simple synchronous gate. Also with the closing of the turbine the cataract apparatus can become wasteful if it is not properly adjusted or if the originally correct adjustment has changed on account of various influences, viz., thickening of the oil, corrosion of the sliding surfaces, foreign bodies between the sliding surfaces. Then one cannot expect any more that with a certain rise of the lever H, corresponding with a certain closure of the supply apparatus, the valve in Fig. 14 or the piston in Fig. 15 is lifted just so high as to give to the water an area to enter the tailrace equal to the reduction of area in the supply apparatus. Rise and drop of pressure in the pipe line, which makes the governor oscillate, are then unavoidable. If then the apparatus remains in the open position, which can happen with the devices as Figs. 14 and 15 on account of sticking, if they are not sufficiently loaded, a considerable amount of water flows needlessly into the tailrace. If then the turbine gets a full load it can happen that not enough water remains to run it, that it slows down more and more and has to be shut down for cleaning the by-pass apparatus.

In electric plants, where frequently a fine is imposed upon interruptions of service, such would be most disagreeable. It is, therefore, advisable to always insert a gate between the pipe

line and the cataract apparatus so that the latter may be cleaned without interruption of service. If, however, such a gate is provided it will mostly happen that the attendants keep it closed all the time, thus feeling safer against disturbances. Especially in winter time, when the formation of ice may obstruct the apparatus in a manner hard to control, it is sometimes unavoidable to shut it down entirely. If then the service is satisfactory without it one cannot blame the attendants if they put it in commission only if visitors come to the hydro-electric power plant.

Conclusions.

From the preceding investigations it follows that under ordinary circumstances, viz., if the maximum velocity of the water in the turbine pipe line does not exceed 6 feet, if the pipe line is not very long, if the pipes are made of sheet iron and if the ratio between the thickness of the material and the diameter does not go beyond a certain point, a danger of rupture does not exist at the quickest possible closures.

If, under a high head and the resulting unfavorable relation between thickness of material and diameter of pipe, danger of rupture exists — this can be determined by formula XI — it has first to be considered whether by reducing the velocity of flow, eventually subdividing the pipe lines, this danger could not be avoided. Then any safety device can be dispensed with, the more so as they not always give a definite guarantee against rupture of pipes and only make the operation of the power plant more complicated. In such cases, where below the power plant the water has to be delivered continuously, by-passes similar to the one shown in Fig. 13 cannot be avoided If, however, the pipe line is very long and with closure within 2 seconds, a danger of rupture still exists, groups of spring balanced safety valves, applied at the lower end of the pipe line, are the simplest and best safety-device.

If in case of rapid loading or unloading of the turbine the governor gets to oscillating badly, on account of considerable pressure rise or drop in the pipe line, the opening of a by-pass, which has to be provided anyhow as a drain, offers a simple means for damping the oscillations. By suitable rules of operation the increases and decreases occurring in the load of the turbine can be made gradual, which considerably lightens the task of the governor. From experiences of the writer the operation of quick-acting governors with high heads and long pipe lines is still

feasible without any device to keep the pressure in the pipe constant, if the ratio of the energy A of the water flowing in the line to the maximum output of the turbine does not exceed the value $B_r = \frac{A}{HP} = 30$, and the fly-wheel masses are so ample that the ratio of the energy of the fly-wheel masses, $\frac{JW^2}{2}$, to the maximum output does not drop below the value $B_m = \frac{JW^2}{2HP} = 300$. Herewith an entirely perfect governor is assumed, whose closing time is 3 seconds as a maximum, with a degree of unsteadiness of the governor of 6 per cent. total. As long as the ratio of the energy of the water in the pipe to the energy of the fly-wheel masses, the characteristic figure $B = \frac{B_r}{B_m} = \frac{1}{10}$ is not exceeded, one can expect the governor to operate without periodic oscillations even without by-pass. This ratio also shows that if B is more than $\frac{1}{10}$ one is not yet compelled to institute by-passes, but can obtain satisfactory working of the governor by increasing the fly-wheel masses.

If the turbine takes little water only the governor wants to be aided occasionally by opening a by-pass, since, as mentioned, the inclination to oscillations of the line (breathing of the pipe line) is the smaller the faster the water flows through same. It always has to be borne in mind that the problem of regulating high-pressure turbines is a problem of vibrations, and an insight into the occurring phenomena is extremely difficult to obtain. The practicing engineer, whose endeavor is always to disclose the occurring phenomena and to reveal their causes, will very likely prefer to avoid all such devices, which, like cataract apparatus, will add to the already complicated conditions some factors which are entirely beyond calculation.

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ROADWAYS AND STREETS.

By Louis C. Kelsey, Member of the Utah Society of Engineers.

[Read at the annual banquet of the Society, May, 1908.]

The term " road " is usually taken to be a way over which vehicles can pass, and carries the idea of a certain amount of artificial construction, maintenance and care; in fact, the word " road " is, as a rule, applied to the artificial construction, in many places usurping the more technical term " pavement." We speak of macadam roads, Telford roads, plank roads, corduroy roads, when in fact it is the pavement of these roads which is meant. It is artificial construction which appeals to the imagination whenever a road is mentioned. It is the contour, the surface, the pavement, in which the average citizen is interested.

It is the locating, the construction and maintenance of this surface or pavement which interest us as engineers. At the beginning of his advancement along the stony footpath leading to civilization it devolved on man to effectively and economically solve the problems of local, interurban, interstate and international traffic. The same problem confronts the engineer to-day. Emperors and kings have studied this problem before us, nations have risen and fallen because of its better or worse solution. Comfort, convenience, health and life are dependent upon the ease, speed and safety with which traffic is handled.

The great railway trunk lines that carry millions of tons of merchandise, the long feeders that traverse our various states in all directions, the little narrow-gage jerk water road that is held up to scorn, vilified as to management, but still patronized by the ever-grumbling public, serve their purposes on land.

The *Mauretania*, the turtle back, the huge battleship, the insignificant-looking torpedo boat, the fishing smack and the barge each serves its purpose on water, but all are dependent for usefulness and even existence on the cart, carriage, wagon, automobile and pack mule. The farmer must market his grain, the merchant deliver his goods, the miner must market his gold and the fisherman, his cod and herrings; without local roads of some kind these are all impossibilities. As the monarch of the forest depends upon the twig, as the great streams depend on the little rivulet, as the great nation depends for its life on the suckling infant, so do the great lines of traffic depend on the truck, the cart and the burro.

Cheops, who, like a half-fledged freshman, scratched his name on all he built and everything that was builded before him, is given the credit of building or paving a road that took 100 000 men ten years. The king of Babylon built or paved three great highways to foster commercial enterprise; Athens, Thebes and Carthage built and maintained roads for hundreds of years, and Rome, mistress of the world, paved that world for the passage of her armies and the transportation of her merchandise, while Gaul had paved trails, a few feet wide, for thousands of miles.

In the new world, the Incas, though supplied with no beasts of burden, yet builded paved footways approximately 2 000 miles long, supplied with shade trees and water. The first pavements made in the new world, after the advent of the white man, were not at the instance of the " city fathers," the " bloated office holders," or even the inhabitants of cities or towns, but were made by loggers, farmers and shipbuilders, of brush, logs and slabs, across swamps and marshes.

The older pavements were all of stone; in some cases these stones were of immense size. Rome used a foundation of lime, mortar and smaller stones, and her finished pavement was 3 ft. thick. This pavement would support enormous loads, but was rough and uneven, even after comparatively short usage. These pavements, on account of the size of the surface stones, were difficult to repair; indeed, the idea, when the first pavements were constructed, appears to have been " solid construction, and use to destruction." Great ruts were worn in the surface of the roads, but the pavement was considered to be in good condition because waterproof and solid. Indeed, when compared with the unpaved streets of London and Paris (the former even as late as the fifteenth century and the latter in the thirteenth century), these pavements might well have been considered the greatest of luxuries.

MacAdam and Telford, of England, were the first to construct cheap, practicable pavements; these pavements, popularly called macadam roads, were hailed with much praise and have been extensively used in Europe, England and America both for country roads and city streets. The materials for construction are obtainable in almost any district and can be prepared by either hand or machinery. The construction is simple and the class of labor required can be obtained anywhere.

It is, however, a popular idea that the construction of macadam pavement does not require technical supervision, either in the selection or deposition of materials; this idea is to a

great extent held by the engineering profession and is one great cause for failure in this class of pavement.

The chief cause for failure, however, is found in the lack of proper appreciation of the need of constant and painstaking repairs. Macadam pavement will deteriorate rapidly and almost irreparably in one season if neglected, causing total loss of the original outlay and frustrating the purpose for which the pavement was constructed. Constant supervision and repair are the price to be paid for even fair macadam roads.

Under the action of horses' hoofs macadam pavements wear solid, and where sheep in large numbers traverse these roads, the surface becomes hard and smooth; the action of the hoofs of the oxen and swine will, however, cause them to wear badly in ruts and holes, the soft cushionlike pads on the soles of their feet producing both a grasping and sucking action which draws the fine particles from between the small surface stones, allowing them to be easily displaced. The same effect, only to a much greater degree, is produced by the action of the pneumatic tires of automobiles and traction vehicles. Engineers watch with interest the effect of these vehicles on the long stretches of macadam roads in England and Europe. From the reports of park commissioners in the eastern part of our own country it would appear that macadam pavements are doomed; only an excessive amount of supervision serves to prevent the formation of ruts or holes which allow the introduction of water and loosening of the surface materials.

The cost of maintenance even under favorable circumstances being very large, by this new destructive factor will probably be increased to prohibition.

Our local experience with macadam has been to the present time limited, no true macadam pavement having been constructed until within the last few years. The sporadic efforts of street commissioners and road supervisors have, as a rule, been discouraging, and the lack of maintenance and supervision already threatens to destroy the macadam pavement constructed by contract.

The asphalt pavements of Salt Lake City are of several varieties, "asphaltic sandstone," "asphaltic limestone," "refined asphalt" and "residual pitch." The foundations for these pavements have invariably been constructed of concrete of good quality, and the pavements as a rule give good satisfaction and good service, though some experimental pavements have not proven satisfactory.

You gentlemen of the engineering profession will, of course, appreciate the value of a solid foundation in engineering work of any character. Concrete is recognized as a material possessing the qualities requisite for a foundation for almost any class of construction. The materials are obtainable in almost any district, the matrix before setting will adapt itself to any and all inequalities of the sub-grade, and, after but a comparatively short time allowed for setting, concrete possesses a strength equal to the best, and far exceeding the ordinary, natural stone. Added to this is its practical indestructibility when protected even to a slight degree. Benefited by the action of water, either in large or small quantities, but slightly affected by the majority of acids, gaining strength with age for an indefinite period, capable of being reinforced with metal and protecting the reinforcing metal from deterioration, concrete is, for construction purposes, the one realization of the ideal.

The wearing surface of asphalt is, as most of you are aware, the thing that is subject to the greater amount of criticism from the layman. This asphalt wearing surface may be roughly divided into two classes, natural and artificial.

The natural product, as used for pavements, is of two classes, "asphaltic limestone" and "asphaltic sandstone," or a combination of the two; these natural products are often refractory and difficult of manipulation, in some cases, possessing the quality of resistance to heat to the point of actual combustion, involving the result that any heat to which they are subject produces no apparent softening in the material until so great as to deteriorate the cementing quality. But few of these natural products can be successfully gaged in hardness or altered in quality without absolute refining. This limits, therefore, their use to such parts as have naturally the requisite qualities for wearing surface. If defective in asphalt, they are too hard; if "long on asphalt" and "short of other materials," they are too soft.

Asphaltic limestone possesses an objectionable quality of being slippery when wet, while the sandstone usually contains earthy matter, tending to cause granulation and consequent deterioration; both of the materials often contain small kidneys of material which deteriorate with exposure, leaving pits or pockets in the surface. Both of these materials, also, often contain large percentages of water and volatile oils which evaporate on exposure, leaving a hard slippery surface in the case of the limestone and a granular friable material in the case of the sandstone products. The impossibility of determining the future

characteristics of any of these natural products is a great objection to their use. A further objection to the natural product is found in its non-adhesiveness to the foundation, and only by the use of the distilled product can this objection be overcome.

Formerly the pavement wearing surfaces in this and other cities were laid directly on the concrete, but the amount of asphaltic cement in the wearing surface was not sufficient to produce adhesion to the foundation; therefore the asphalt was inclined to crawl or creep. This action may, however, to a large extent be obviated by the use of a binder composed of refined asphalt and broken stone, the use of the natural asphalt being confined to the wearing surface.

Paving with refined asphaltum appears almost an exact science when compared with the use of the natural materials, with the additional advantage of less cost. The binder course prepared with sharp, hard, broken stone mixed with asphaltic cement effectually prevents the creeping or crawling of the wearing surface. The wearing surface, composed of stone dust, sand, Portland cement and asphaltic cement, can be so gaged and mixed that the resulting matrix is of the exact quality, as regards density and flexibility, fitting climatic and traffic conditions. The admixture of sharp, hard sand with the asphaltic cement produces a surface fitted for traction vehicles, smooth but not oily, while horses find a footing much superior to wood, vitrified brick or cobblestones. As the vehicle resistance is entirely due to traction and not to either adhesion or rough surface, the propulsion of vehicles is easily accomplished. The surface is easily cleaned by the use of either water or brooms, the material is absolutely dustless in itself, sanitary, even to a certain extent antiseptic in its action, and even heavy traffic is beneficial to asphalt when proper width is allowed on wagon tires. Asphalt pavement on roadways of ordinary gradient approaches more nearly the ideal than any other pavement exploited.

There is, however, room for many improvements in the construction of the roadways. On streets of any length the question of expansion of the foundation is a serious one. Asphaltum expansion joints have been suggested and some experiments have been made with this material; they have, however, been to a great extent failures.

The proper construction of the joints along gutters and manhole covers is another serious problem which is worthy of the attention of engineers.

A far more serious question has arisen not only in our own

city, but in almost every city in the United States where pavements have been constructed; this is the question of the proper pavement for roadways having a steep gradient. Asphalt pavement can, it is true, be so constructed that it will furnish good footing for horses or traction for automatic vehicles on almost any practicable grade, as long as the surface is kept free from ice or snow. In our northern cities during the winter months this becomes an impossibility. If the snow was of such depth as to entirely form the traffic roadway, horses would be able to obtain footing if properly shod, but where the pavement is covered or partially covered with thin ice, or heavy frost, it becomes necessary to furnish a rough surface to insure good results. Brick, stone, concrete and wood have been successively tried, and each is open to serious objections. Whether it is possible to produce a satisfactory footing surface for winter traffic on steep grades is questionable. Some cities have resorted to the spreading of sand upon the paved surfaces, but this is also objectionable, and is only a very temporary relief, a slight snow or rain serving to render the work ineffectual.

Before ending this paper I wish to touch on the cheapest roadway that has so far been constructed, "an earthen turnpike," so called.

There is no doubt that the crowning of a roadway, even of earth, will greatly improve the drainage and surface conditions, and street supervisors should be encouraged to properly do this work. An earthen roadway should have a much steeper crown than is ordinarily given, and should not only be continuously sprinkled, but rolled, to keep in good repair.

Oiled turnpikes have been tried with some success in different cities, but they possess one objectionable feature that is inherent in the materials of construction. The action of even small particles of oil on rubber is exceedingly destructive; even the smallest particle of oil will in a short time cause irreparable damage to rubber tires. If the roadways were to be used by vehicles having metallic tires, oiled turnpikes would be a convenient substitute for macadam. That the oil is effective in lessening the dust there can be no doubt but its destructive effects on both clothing and rubber tires is no less apparent.

These objections are, however, reduced to a minimum, where the material used is asphaltic oil from which the lighter and more volatile oils have been eliminated by distillation.

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PRACTICAL METHODS OF EXAMINING AND FITTING UP A HYDRAULIC MINE.

By H. A. Brigham, Member of the Technical Society of the Pacific Coast.

[Read before the Society, August 28, 1908.]

It is the purpose of the author to present to the engineering profession a brief review of the methods of hydraulic mining that were so successfully applied for many years in California, where these methods originated because they solved a problem; that is, it became essential to find ways and means to extract economically from the gravels the gold that nature had stored there in ages past for the use of man, and the unique manner of mastering the situation has found, and always will find, the admiration and approbation of technical men of all countries. It is so practical and simple a process that its utilization in mining will always remain an alluring expedient, and where the requirements for its successful operation exist, it seems almost a calamity to the commonwealth that it should have ceased to be the great industry it once was; and it is not unreasonable to assert that with an intelligent study of the physical surroundings it should be possible now, under certain conditions, of course, to make practical use of hydraulic mining on a large scale again.

That its processes may become familiar to others who have not had the opportunity to study its methods and results, the author has thought it of sufficient interest to describe, as briefly as that may be done, the practices of the old hydraulic miner, drawing mainly from his long experiences of many years past, dating back to the time when hydraulic mining was in its infancy in this country, and when it grew from small dimensions to assume cyclopean and colossal proportions.

While it is not the intention of the author to enter into any of the arguments and discussions that have been made so often, before the time and since the time that hydraulic mining was enjoined in the most promising part of our famous state, it does seem to him as though our technical men, our engineers and scientists should not give up all hope of an ultimate solution of this problem of rehabilitation, a problem which is worthy and deserving of the keenest attention of our greatest intellects, and

the magnitude of which should stimulate them to their best and noblest efforts.

The problem is worthy of it.

To give a bare outline of the possibilities of a part of the once famous hydraulic mining region of the Sierras, it may be stated in this connection that the ancient gravel channel, extending from French Corral on the west (lower end) to Moores Flat on the east, in Nevada County, Cal., covering a distance of some twenty-three miles, was probably the most extensive auriferous gravel deposit workable by hydraulic method known in the world.

The Columbia Hill section of this channel, reaching from Columbia Hill on the east to Cherokee and Badger Hill on the west, has only been worked in small and limited portions. It is about four miles long, over a mile wide in places, covering an area of more than two thousand acres, with a maximum depth of over 500 ft. This channel at a conservative average depth contains upwards of 900 million cu. yds. that hold out every inducement for profitable hydraulic mining, if means are found to carry away the tailings without restriction. This deposit is entirely free from overlying lava or other worthless material, containing little clay or bowlders of a size detrimental to hydraulic methods, except perhaps at the bottom, in the lower stratum, where larger bowlders are to be found. Gold lies here in paying quantities, distributed from the top to the bottom of this great gravel deposit; at the rate of ten cents a cubic yard which is a very conservative estimate, the treasure lying there and ready to be taken away represents 90 million dollars. It seems as though this were worthy of some thought and consideration. This region has been hydraulicked in a small way at any and all levels. Three different benches have been worked at several distinct points, in a haphazard way, leaving still a depth of at least 300 ft. of virgin gravel below the bottom of present operations.

A few statements of the results of actual workings may convey an idea of the wealth of this great mining field and of its future possibilities.

At the upper end of this deposit, at the Blue Bank Mine, Moores Flat, gold to the value of 91 000 dollars was taken out of an area somewhat less than one half an acre; this was the last hydraulic mining done at that end of the channel. At the very end of this hydraulic period a gross result of 29 000 dollars was achieved in a run of twenty days, dating from the preceding clean-up, netting more than 22 500 dollars for the run. The last

year's operation of the North Bloomfield Mining Company, ending at the time when the injunction was decided against hydraulic mining by the United States Circuit Court, netted a sum exceeding 300 000 dollars.

The following well-known mines are included in this section of the ancient gravel channel: the North Bloomfield, the Eureka Lake and Yuba Canal Company Consolidated, the Milton Mining Company,— all hydraulic mines,— besides several other very extensive hydraulic properties. Owing to the difficulties of working these deep deposits, requiring long drain tunnels, this part of the ancient channel, including the towns of Cherokee, Columbia Hill, Lake City, Malakoff and North Bloomfield, has been hydraulicked to the bedrock at only three points, viz., Moores Flat at the upper end, North Bloomfield and Malakoff some six miles below Moores Flat, and Badger Hill at the lower end. These statements are made to show that the process to be described has great possibilities.

There are no difficulties in the way of getting the gold out of the ground if we can agree upon some method by which we may dispose of the refuse material that holds this coveted metal in its grasp.

EXAMINATION OF A HYDRAULIC MINING PROPERTY.

Hydraulic mining consists of excavating and washing gravel by water under pressure through sluiceways provided with riffles for catching and saving the gold.

To make profitable use of this method it is essential to have a large volume of gravel containing sufficient gold, an adequate grade to utilize the sluices properly, dumping facilities for the disposal of the tailings, ample water under effective pressure for breaking down and washing off the material, and a supply of timber for building sluices or for other purposes.

Preliminary Examination.

In making an examination of a hydraulic mining property a general view of its situation, conditions and capabilities should be taken from the more elevated localities in its vicinity. If the view from these higher elevations is not too much obstructed it should be possible, with an aneroid and with a hand and slope level, to ascertain the general conditions and the adaptability of the locality for the purpose. This means an approximate determination of height, length, width and amount of the deposit to

be handled, and its general trend; the elevation of the bedrock of the channel or bottom of gravel deposit to be worked; the outlets and dumps for tailings, their relations to the height of the channel and the distance therefrom; the conditions and facilities for disposing of the tailings; the elevation, length, grade, required size, etc., of the sluices; the amount of water available, and the facilities for bringing it to the mine for economical and effective use; practical reservoir sites, both for storage, if necessary, and for receiving and distributing the water; available timber for building sluices and for general use; facilities for transporting the necessary material and supplies needed; labor conditions, climate, etc.

Detailed Examination.

If the view from these elevated positions should be too much obstructed to obtain the general oversight needed to form an opinion, and if no impossible conditions have been previously encountered, then more elaborate surveys may be necessary for obtaining this required information.

But if no feature is found fatal to the project, and all features appear reasonably good, then a more extensive and detailed examination should be entered into, commencing first with the *Titles*, which, if found perfect, should be succeeded by a very careful and exhaustive test of the deposits as to their value, extent, location, character, etc., and as to the elevation, formation, position and nature of the bedrock of the channel, or the bottom of the deposit to be worked. The methods of procedure for these tests will have suggested themselves from the preliminary examination; that is, whether by shafts, bore-holes, tunnels, cuts, exposed faces or otherwise.

Many and numerous samples should be carefully selected from all sections, or, at least, from a sufficient area, in order to enable one to arrive at a general average value; the extent of the entire deposit and the elevation of the bottom of such deposit should also be taken into account. A diagram should be made showing the immediate individual locality from which each sample was obtained. All the samples should be marked and carefully weighed; they should be reduced by pan or rocker, and the resulting gold, accurately determined and tabulated, should be finally entered upon the plan at the proper position.

If water in sufficient quantities can be obtained for the purpose, and conditions are favorable, an excellent method is to work off a measured section of the deposit by piping, or ground sluicing

through, or by shoveling it into small sluiceboxes prepared for this test. This plan, however, while giving a larger and consequently a better general average value than the pan or rocker test, may not be so reliable, owing to the greater difficulty in preventing a falsification of the natural conditions of the deposits, and this may call for an additional check.

The thoroughness, care and caution observed in locating and testing the deposit, and in ascertaining the position of the channel, bedrock or bottom of the deposit, are of the utmost importance, as the success of the whole undertaking is centered in and dependent almost entirely upon the reliability of these tests, and all the future examinations will be governed by and related to them.

When the results of this investigation have been satisfactorily verified, sufficient information as to the bedrock conditions should have been obtained to enable one to establish the elevation of the upper end of the sluice.

If all these preliminaries prove satisfactory, the next step should be to investigate the available outlet or outlets, dumpage facilities, and character of the bedrock or other ground through which the sluice will pass, whether by cut or tunnel; all these details should be thoroughly examined.

The elevation, grade and pavement of the sluices are of paramount importance, for the steeper the grade and the smoother the pavement, the greater the volume of fine material, and the larger the quantity and the sizes of stones and bowlders that can be run off with a given amount of water. Most large hydraulic mines have not fall enough, and are compelled, by their conditions, to be worked on inadequate grades. The determination of the elevation and grade of the sluice will depend upon the elevation and general condition of the available dump for the tailings, and also upon the relative positions of dump and deposit as to height and distance between them, as well as upon the amount of material to be deposited in the dump.

If the tailings can be discharged, firstly, into a torrential stream of sufficient size and current to run them away immediately and effectually; or, secondly, into a ravine or channel of ample grade or fall to carry them off by their own water; or, thirdly, if they can be discharged over a precipitous place where they will never accumulate high enough to back up into the sluices, the disposition may be considered as ideal, and the elevation of the lower end of the sluice may be established at once.

But if the tailings must be discharged into a place where

they will accumulate detrimentally, it will be necessary to observe that the sluice be located high enough to prevent any deposits at elevations that will cause them to back up into the sluice, choke it and render it unfit for further operations on that grade.

To establish the proper elevation for the lower end of the sluice under such unfavorable conditions of dump, surveys are necessary to determine the storage space available below the grade of the sluice and to obtain an estimate of the amount of material to be washed off and the proportion that will remain in the dump. If the ordinary conditions make the slope or grade too small, it may be possible to place the dump end of the sluice at a lower level and to utilize a giant near the outlet to elevate or stack up the tailings on one or both sides of the line of the sluice, to be extended as the dump becomes filled; or, the upper end may be placed at a higher level with the installation of a hydraulic elevator to lift the water and gravel into the head of the main sluice. Either one of these arrangements — giant at the dump end or hydraulic elevator at upper end of the sluice — will provide a steeper grade.

A giant or monitor is a device attached to the end of the mine pipe line, by which the stream may be controlled in direction. It consists of a metal tube so fixed to the pipe by flexible joints as to be moved readily in both planes. The tapering nozzle end varies in diameter from 4 to 9 in. and has a deflector attached at its extremity for the purpose of directing the stream readily to the proper point of attack.

This instrument of attack is the main implement of the hydraulic miner, and its successful development has made the process of hydraulicking what it finally became. It places a powerful stream of water, a confined force of great magnitude, at the immediate disposal of the operator, who utilizes this force by directing it, according to his judgment, to the point of attack. The width and the proportions of the sluice are governed principally by the volume of water to be used, and, to a small extent, by the character of the material to be washed, sand and fine gravel requiring a wider sluice, while large bowlders should have a narrower one for a given quantity of water.

For washing fine material and sand the following widths for sluices under varying amounts of water will answer, viz.:

For a 3-ft. sluice, 200 to 600 miner's inches of water.
For a 4-ft. sluice, 400 to 1 200 miner's inches of water.
For a 5-ft. sluice, 1 000 to 2 500 miner's inches of water.

For a 6-ft. sluice, 2 000 to 4 000 miner's inches of water.
For a 8-ft. sluice, 3 000 to 5 000 miner's inches of water.
For a 10-ft. sluice, 4 000 to 7 000 miner's inches of water.

If the deposit contain many large bowlders, the above proportions of water may be increased 10 per cent., or perhaps more.

The "miner's inch" varies greatly in different localities and is here assumed as equivalent to $1\frac{1}{2}$ cu. ft. per minute.

Most hydraulic mines contain more or less fine gold which cannot be saved with the ordinary sluices, no matter how well the sluice is paved or how carefully it is manipulated. Under such circumstances, if conditions make it permissible, one or more undercurrents are very desirable. It is preferable to locate them near and below the lower end of the main sluice, for the reason that by placing them midway, fully five feet of the available grade will be sacrificed in order to lead the water and tailings from the undercurrent back into the main sluice again.

By undercurrent the hydraulic miner means an enlarged construction of the lower end of the sluice, which is more particularly described hereafter and shown in the appended illustrations in detail. (See Sheet No. 3.) It is provided for the purpose of receiving the finer material, containing the fine gold which would escape without this precautionary measure, together with a certain quantity of the water in which this material is conveyed. The water, which is spread over a greater surface, slackens its speed of current, and this allows the smaller particles of the gold to settle in the riffles more readily. An undercurrent, therefore, arrests the flow more effectually than a sluice and retains any gold that the sluice may have allowed to escape.

Water Supply.

The matter of water supply for working the property should be thoroughly investigated. The quantity available, the amount of regular and constant supply, the height at which it may be delivered at the mine, the length of the ditch necessary to convey it and its proper grade, the character of the ground over which the ditch line or lines will pass; the necessity for flumes, the supply of timber for building them as well as for other purposes; the necessity of using pipe lines for crossing ravines or depressions and their length, size, pressure, etc., are features that require detailed inquiry.

If the supply of water is limited during the dry season, a survey of the drainage area and available sites for storage reservoirs may be requisite. It is necessary to ascertain the condi-

tions of the drainage area and the character of the soil for retaining the water; also the annual rainfall and how this is distributed through the different seasons of the year, as it is essential to have as steady and constant a supply of water assured as practicable in order that the washing may be carried on with as little interruption as possible.

The grade of the ditch should be as steep as permissible, taking into consideration the height at which the water is required at the mine and the nature of the ground traversed by the ditch. The cutting or eroding action of too swift a current for the soil must be avoided. The ditch must not deteriorate by the scouring action of the water running in it, and to prevent this its grade should be accommodated to the nature of the material into which it is cut.

Receiving Reservoirs.

One or more receiving or distributing reservoirs are very essential, and their capacity will depend upon the character of the deposit to be worked and the facilities for handling it.

If there is a wide face to the mine, so that washing may be carried on at several different points independently, or if there is little pipe clay and few bowlders to handle, and the material easily broken down and washed; if there are no hard bedrock cuts to excavate, and if the main line ditch is short and there is ample storage above the ditch line, then a small receiving reservoir will answer. But if the face is narrow and contracted, and there is much pipe clay to be broken, or many bowlders or stumps that require blasting and removal; or if there is much hard bedrock to be blown away, and with no storage facilities above the ditch, then receiving reservoirs of large capacity should be provided to prevent waste during the interim of cleaning up, shifting the giants, removing bowlders, etc., or while doing other work around the mine.

One of the receiving reservoirs should be near the head of the mine pipe line, so that the water may be quickly regulated for the giants or turned off without waste in case of accidents or other causes.

Cleaning Up.

This is the hydraulic miner's harvest, and consists in removing the pavement, collecting and separating the gold from the sand and from the material lodged in the riffles or interstices of the sluice pavement, a process that will be referred to again hereafter.

Pipes for the Mine.

The pipes that lead the water to the giants at the mine should be of ample capacity for carrying the entire quantity to be used without undue friction; seldom, if ever, is it good practice to run a portion of the water for the sluice over the bank. The pressure should be such as to allow the giants to be operated at a safe distance from the face, to prevent them from being injured or buried by the falling bank, and yet exert sufficient force to undermine the bank rapidly enough to insure an ample supply of gravel for the sluices.

It frequently happens that the lower portions of the bank are so compact or cemented that sufficient stream pressure cannot be obtained to cut it speedily enough to supply the sluice; other methods will then have to be resorted to. In such an event, it may be possible to get an ample supply of material for the sluice by piping above the hard gravel into a softer stratum, and far enough ahead to insure the safety of the giant from caves; the giant may then be brought closer to the bank, where it may now exert sufficient force to remove the remaining hard portion. While it may not be possible to cut this stratum fast enough to supply the full capacity of the sluice, it may be so arranged that one giant could be at work on this hard part of the bank while another could furnish the remainder of the gravel supply from a softer or caved portion of it.

Sometimes blasting has to be resorted to for loosening this hard material, which may be done by working the top off first and then blasting the remaining portion by means of drill holes, shafts or drifts; or it may be preferable to blast the entire face by running powder drifts into the bank at the bottom, with cross drifts at right angles at their inner ends; in this case, the powder is placed in the cross drifts and the main drift tamped solidly with dirt before exploding.

The latter method of blasting the entire bank, while frequently resorted to in the earlier days of hydraulic mining, when small streams of water were used, is now seldom required, as the large streams of water under high pressure as now employed are generally able to overcome the difficulty.

Details of Installing the Plant.

In discussing the preliminary examination for the exploitation of mining property, enough has been said heretofore to point to the fact that the arrangement of the sluice becomes one of the most important elements in the fitting up of the mine, for no

problem requires better judgment and more careful thought than the establishment of the grade, determined by the beginning and end elevations of the sluice and the distance between these two points.

With great hydraulic forces obedient to our immediate command, it is comparatively simple to remove large masses of material, and very cheaply, too; the principal difficulty, however, arises in providing an efficient carrier to convey them to the locality of disposition,— a conveyor that will always perform its many important functions with the least interruption or loss of time

It will be instructive, therefore, to discuss the practical installation of a sluice with more detail, referring to the preceding statements for a knowledge of the general principles that must guide one in determining the practical and economical possibilities, and also in studying the topography for the selection of the line.

The Sluice.

Practically this is nothing more or less than a flume of special design, built for the purpose of conveying water, which is, again, the conveyor of gravel containing a valuable metal that must be segregated from the mass and saved by making use of its greater specific weight. (See Sheet No. 2.)

The available cross-section may have a width of from 2 to 12 ft. or even more, and a height of from 2 to 4 ft., according to the volume of water used; it is made up of the sill, the posts and the side braces, the lining of floor and sides, and the walking plank on each side. There are no cross caps. The sluice contains the floor device for catching the precious metal, which, although almost primitive in its mechanical simplicity, is practically very effective and has been in use in one form or another from the earliest time in the history of gold washing. It consists of a pavement (which may be of wood, or of stone, or even of iron; in fact, of any suitable material), so placed and arranged that the greatest amount of gravel may be effectually conveyed over its surface; at the same time it will have to afford the gold an opportunity to leave the mass in which it is moving along; it must intercept it and find lodgment for it in the numerous pockets, or receptacles, that have been provided between the blocks for that specific purpose.

Reference may be had to the illustration shown on Sheets Nos. 2 and 3 for details of construction.

In constructing the sluice, great care must be taken that the grade be uniform throughout its length, as a short section of lighter grade will govern the transporting power of the material for its entire length, while a section on a steeper gradient will cause a more rapid wear of the pavement, and this may necessitate a change or renewal of it on the steeper grade before it is really required on the rest.

A straight sluice is an ideal one, but this is not always practicable. In making turns or bends in a sluice, great care should be taken not to make angles so sharp that the flow of the water is thereby retarded or the surface of the water unduly disturbed which will cause a stoppage of the material, thereby choking up the sluice. Where an abrupt bend is unavoidable, it must be so constructed that the current will adapt itself to the turn and retain its velocity and smooth water surface. This can be accomplished by cutting the sluice boxes into such lengths that a short turn may be effected by a small curvature to each joint.

Where the proposed turn cannot be made with the full length (12 ft.) of the boxes, by giving each box a 5-in. turn, the boxes may be made in shorter lengths, say 6 ft., each of a 4-in. turn; if necessary to make a still shorter curve, the boxes may be made 4 ft. long each, with a $3\frac{1}{2}$-in. turn; even shorter lengths may be used if necessity requires it. At both ends of a curve the turn should be eased.

The outer curve, or that of the longer radius, should be raised a little above the inner one, say $\frac{1}{8}$ to possibly as much as $\frac{3}{8}$ of an inch per foot of sluice width, at the same time increasing the grade a little to overcome the check. Around a very short turn the gradient should be increased as much as 15 per cent., or possibly a little more than that. With this precaution few instances are likely to occur where a turn cannot be successfully made without sacrificing more than a few inches of the available grade.

The height of the sluice — the sides — will depend upon the height and condition of the ground through which it passes. If the sluice is to be in a deep cut, in hard ground, high sides will be unnecessary, and 30 inches may be enough. This will not only save lumber but it will also prevent a heavy strain on the sluice bottom, and, in the case of cleaning up and changing the pavement, it will afford a handier opportunity for piling the loose blocks on the top, which is so much easier to reach.

If a sluice located in a deep cut of hard material as just described should fill to overflowing because the gravel is run into

it too quickly, or if it be obstructed in any way to cause an overflow, the water will at once return to the sluice without aid as soon as the flow of the gravel is reduced or the obstruction removed. On the other hand, if the ground of the outer cut is soft and liable to be eroded by the created current, or if it lie lower than the top of the sluice, care must be taken that the sides are high enough to prevent any overflow during an obstruction, for if this should occur in a case like this, even to a slight extent, while the sluice is fully charged with material, it would cause a congestion, and unless the flow of gravel from the mine be checked immediately, the entire head of water will overflow the sides, and it cannot be brought into the sluice again until the gravel is removed, which will cause a long and expensive delay.

Preparing the Bed for the Sluice.

Where the sluice is to be laid in a deep open cut, and the character of the ground is such that it may be washed away, and where the necessary quantity of water may be had under adequate pressure, it will prove economical both as to time and cost to utilize a giant in preparing the bed for the sluice. If water be available, but without pressure, recourse may be had to ground sluicing. The bed may be prepared in this way by getting it almost down to the proper grade and finishing it by hand labor subsequently.

Where there is a large amount of material to be removed in this manner in order to prepare the bed for the sluice, a section may be hydraulicked or washed off and the sluices built therein and paved; it may then be possible and practicable to work off another section of the ground through the sluice already completed.

In this way the sluices may be extended and continued until the field of operation is reached.

Tunnel.

In opening up a mine, a drain tunnel for the sluice is sometimes necessary, with a shaft at its head for the purpose of washing the material through it into the sluice in the tunnel.

The tunnel should be of sufficient width to afford room to place the loose pavement upon the top of the sluice while cleaning up and changing it. While it is possible to place the loose pavement on the bottom of the sluice at such time, it becomes a slow and awkward process, as it must be shifted several times before completing the clean-up. If the head of a sluice tunnel is located

in deep bedrock, or if a shaft is used for any length of time in running material through it, the portion that is subjected to the continuous wear and tear for long periods should be securely timbered and lined to prevent its ultimate destruction.

Should the bottom of the shaft be in soft ground, liable to be eroded by falling water and material, it must be securely timbered to prevent undermining at its lower end. If the bedrock be very soft, it may be necessary to extend the timbering of the shaft downwards a few feet below the bottom of the sluice. The bottom needs no protection other than to prevent the sides from caving.

In order to prevent a choking of the tunnel from an oversupply of gravel, it should be made somewhat higher from the shaft downwards for a distance of 50 feet or more, say, to the extent of 3 or 4 feet at the shaft and tapering thence to the normal height of the main tunnel in this distance. If the tunnel is to be continued past the shaft it will prove expedient to place the shaft to one side of the tunnel and far enough from it so that the shaft may be utilized for washing the material, or for running waste water through it without endangering the sluice after its extension ahead and beyond the shaft. This can be done by running a short branch from the main tunnel and placing the shaft at the head of this branch.

The main tunnel should be extended ahead at opportune times and another shaft constructed to be in readiness for continuing the washing without delay when the cuts from the former shaft lose their grade, become too deep in the bedrock or too long to justify their farther extension.

If, in placing the sluice in the tunnel, there should not be sufficient room on each side to put the loose pavement while cleaning up, the sluice should be placed close to one side, leaving all the space on the opposite side.

Drains.

If there be a large quantity of seepage water from the mine, t may be desired to construct a drainage box for conveying this water during the time that the pavement is replaced. This drain may be located on the outside of the sluice, its upper elevation even with the top of it. While this will require a high temporary dam to raise the water into the drain at the upper end of the section to be cleaned up, it has the advantage of clearing easily, while clearing would be difficult with a closed drain placed on a level with the bottom of the sluice, as is sometimes done. Unless

there is a large amount of seepage water to handle, the drain may be dispensed with, for the miners soon become accustomed to paving the sluice with considerable water running in it.

Before turning on the water for mining, a signal should be placed near the upper end of the tunnel, a short distance below the shaft, with a connection therefrom to some point where it can be readily seen from the mine, so that it may be indicated at once if the sluice begins to fill with an overload of material, or from some other cause, so that the water may be allowed to run free of material until the sluice clears itself, when washing may be resumed.

Construction of the Sluice.

This may be seen in detail on the illustration shown on Sheet No. 2.

For the bottom $1\frac{1}{2}$-in. boards will answer and for the sides $1\frac{1}{4}$-in. The bottom is to be surfaced on the top, the sides to be left in the rough. The sills may be 4 by 5 in. for sluices up to 5 ft. wide, and 4 by 6 in. for wider sluices.

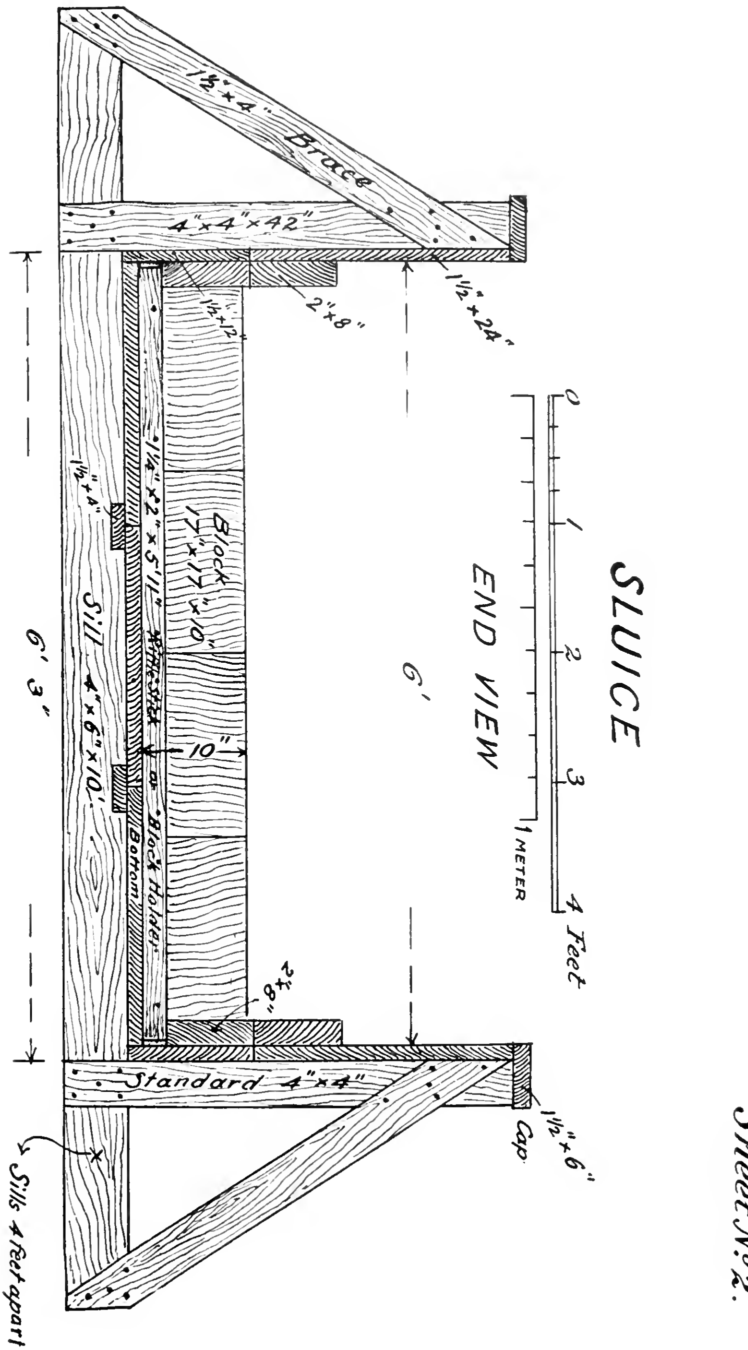
The posts or standards are suitable at 4 by 4 in., and the post braces should be of $1\frac{1}{2}$- by 4-in. timber. The bottom ties must be firmly laid so that no settlement will occur if the sluice should become filled with gravel. All joints in the bottom should close perfectly to prevent leakage of quicksilver and consequent loss of fine gold.

If there be springs along the line of the sluice, their water should not be allowed to back up and run over the top, as the pressure may force up the bottom, especially while cleaning up. Cutting a vent hole near the end of the side board, $\frac{1}{2}$ in. above the bottom board, with the bottom side of the hole sloped upwards towards the outside of the sluice, to prevent the quicksilver from running out, will overcome this difficulty. Several of these holes should be made along the sluice, especially where there is danger of water backing up on the outside.

A longitudinal cap or running board, say $1\frac{1}{2}$ by 6 in., should be securely placed on the top of the sides, nailed flush with the inner edge of the side board to prevent this from bulging into the sluice. The sides should be well braced against inward or outward bending. The sluice must be anchored down and well protected from rising bodily, which may be caused by exterior water pressure.

Pavement.

If suitable timber may be obtained at reasonable prices, a block pavement is generally the most desirable, especially for


SLUICE
END VIEW
Sheet No. 2.
1½"×4" Brace
4"×4"×42"
1½"×24"
2"×8"
1½"×12"
6'
0
1
2
3
4 Feet
1 METER
Block 17"×17"×10"
1¼"×2"×5'11"
or Block Holder
Bottom
10"
1½"×4"
Sill 4"×6"×10'
6' 3"
2"×8"
Standard 4"×4"
1½"×6"
Cap
Sills 4 Feet apart
Brigham "Hydraulic Mining"

the upper end of the sluice where the principal portion of the gold particles will settle, and where the pavement will have to be removed more frequently for this reason. If the sluice must be longer than necessary for the simple saving of the gold, it may be desirable to pave the lower portion with other material, if a suitable kind is obtainable and at reasonable cost.

Rocks or bowlders make a lasting pavement and, under favorable conditions, may be desirable if of very hard material and of such shape that they may be securely held in place, particularly if they do not present too uneven a surface for the gravel and bowlders to run over. Rocks blasted by dynamite are not suitable for pavement, owing to the shattering effects of the dynamite.

It will be almost impossible to pave a sluice with stones and to make a surface so smooth and even that the same amount of gravel and bowlders can be run over it that will run over a block pavement on the same grade; therefore the portion paved with rock should have a proportionate increase of grade. This is of great importance as the volume of gravel and bowlders that can be run through the sluice depends upon the amount that can pass its section of least transportability; that is, that particular portion which has the least grade or the most uneven surface.

If very hard rock be used in the pavement it will probably outwear any block pavement five or more times in the matter of requiring it to be changed by reason of an uneven wear.

The problem of working successfully by hydraulic process is this:

To get as much material into the water as the current will transport through the sluice, and to convey this volume continuously without interruption.

Steel bars and old railway iron make a very good pavement, for as much fine material and more bowlders can be run over them than over a block surface. This iron pavement is generally more expensive, especially if the mine is situated at a great distance from a railway and lacking cheap transportation facilities. But it has the advantage of wearing much longer than blocks, and it needs less changing in consequence, an operation that always constitutes one of the largest expenditures and delays in hydraulic mining, especially where there are block pavements in long sluices.

Details of Block Pavement.

Blocks for pavement are generally made by sawing them from the trees in lengths suitable for the purpose for which they

are to be used, say from 4 inches long, where a small head of water is to be used, to 12 inches, or even more, where a large volume of water is run. These blocks are squared to such a size that a given number will reach across and just fill the sluice from side lining to side lining. One or more different sizes may be used for the same sluice, but each size should be square, so that when replacing the pavement the blocks may be turned around in any manner best suited to make the smoothest surface possible. (See illustration, Sheet No. 2.)

It is very essential that the blocks be hewn squarely and truly and placed so tightly together that no crevice is left parallel with the current, for a small crack, more particularly if two or more are in line, will soon become larger by wear and will compel a cleaning-up and a change of the block system sooner than if this had been properly laid the first time; the wear, in that case, will be so irregular that it will be found most difficult to relay a satisfactory and smooth surface again without eliminating the uneven blocks.

Side Lining.

The side lining of the sluice shown in the section on Sheet 2 as two 2 by 8 in. planks on each side has two purposes: To protect the permanent side of the sluice from being worn, and to hold the blocks and prevent them from rising and floating away. (See Sheet No. 2.) The thickness of the side lining will depend upon the width of the sluice and the quantity of water used.

With a narrow sluice and a small head of water, 1-in. lining will answer, while with a wide sluice and large volume of water, 2- to 3-in. lining is required, and this should reach sufficiently above the blocks to prevent the wear of the permanent side planking.

Boards are generally used for this purpose, but where there is a large amount of wear, blocks are sometimes utilized, especially if the sluice is located in a tunnel or at other places where it is inconvenient to change the lining.

These blocks are made somewhat similar to block pavement by sawing them in $2\frac{1}{2}$ to 3-inch lengths from the tree, dressed to uniform sizes for top and bottom, and of any convenient length for the sluice. They are nailed to the side similar to board lining.

Riffle Strips or Block Holders.

These strips or sticks answer two purposes also: To hold the blocks in place and prevent their floatage, and to create the in-

tervening space, crosswise in the sluice, between two series of blocks, known as the riffle, whose office it is to hold the quicksilver and to catch and retain the gold particles.

The dimensions of the sticks vary under different conditions and under differing opinions of miners. They must be strong enough to prevent the blocks from lifting and broad enough to furnish an ample-sized receptacle between the blocks to harvest the gold. The thicker or broader they are, that is, the wider the space between the blocks, the greater and the more uneven will be the wear on the block edges, and, consequently, the rougher will be the surface of such a pavement after the blocks have been turned and changed around.

If large bowlders, especially angular ones, be run over a pavement, it will become manifest that the wider the riffle, the more will the lower edge of the blocks be broomed and split off, which will make a very rough surface upon turning.

If the " riffle pieces " are too high, the receptacle for the gold will become shallow and sometimes obliterated when the pavement is worn thin. A " riffle strip " $1\frac{1}{4}$ by 2 in. is sufficiently strong for a sluice 5 ft. wide; a wider sluice requires a stick of $1\frac{1}{4}$ by 3 in. dimensions. (See the illustration on Sheet No. 2.)

Laying a Block Pavement.

A good method is to nail the side lining against the permanent side of the sluice, leaving the lower edge $2\frac{1}{4}$ inches above the bottom, where a 2-inch riffle strip is to be used, which will allow the end of the riffle strip to be freely inserted under it for the purpose of preventing the strip from lifting with the blocks when the water is turned on.

After the side lining is properly secured to the permanent side of the sluice, a row of blocks, all of the same size, is placed across it and wedged tightly together and against one of the side linings; thereupon a riffle stick is slipped under the side lining and pushed against the side of the blocks, raised up tightly against the bottom of the lining and nailed to each block with headless or small-headed nails, leaving $\frac{5}{8}$ of an inch of the head projecting for insertion into the next row of blocks.

After one row is properly secured in the manner described, another row of blocks is placed across the sluices, the blocks are pried close together and set up tight against the side lining, in this case opposite to that wedged to in the case of the preceding row, and in this manner breaking joints in the block system. The blocks are thereupon driven solidly on to the nails and

against the riffle stick. Another riffle stick is inserted after this, and the process is repeated in the same manner as just described and continued in both directions, up and down the sluice, provided there is no running water in it to interfere with the laying up stream.

After the entire sluice is properly paved and everything in readiness for the water to be turned on, washing should be commenced with a small head of water until all the spaces are solidly filled with sand and fine gravel, after which the full head of water may be utilized.

In beginning to wash through a new sluice, where the ground on the outside is higher than the top of the pavement, caution must be used that the water does not collect on the outside to a greater height than on the inside, unless the sluice has already been properly anchored or weighted down. Unless it has been filled solidly with rock or dirt to the top exteriorly, it should at once be made to overflow until the outside is filled completely with dirt, even with the top, if possible, after which, if this be properly done, no further anxiety need be had as to the possibility of lifting the sluice.

If the channel or face of the gravel deposit to be worked is too wide to be washed through a single sluice or cut, one or more branches are made necessary from somewhere near the head of the main sluice.

The distance between these branch cuts or auxiliary sluices will depend upon the character of the gravel deposit; in the case of a deposit containing much hard clay to be broken up, or large quantities of bowlders to be conveyed, these branches should be nearer together than in a case where the deposit is composed entirely of fine gravel and sand.

If the deposit contains adhesive clay, especially near its bottom, so that it cannot be worked separately and apart from the pay-gravel, then the branches should be close to each other and held at such a steep grade that they will keep themselves entirely clear, allowing nothing to collect therein while washing this pay-gravel; or, what may be still better, the sluices should be built up as closely to the bank as possible, to secure the gold quickly from the clay, for the reason that the sticky clay has a decided tendency to take up all the gold that it may come in contact with, and it will carry all this, or nearly all that it has once picked up, entirely through the sluice and away from the undercurrents at a total loss to the mine. Where the deposit is very deep and extensive it may be advisable to hydraulic it

off in two or more successive benches, which will give a steeper grade for working the upper levels.

Speaking generally, a bank of 250 to 300 ft. is as high as can be conveniently hydraulicked in one bench, although, under favorable conditions, it may be practicable to work with safety from a single bench a bank that exceeds 300 ft. in height. These conditions are: A large pressure for the giants; compact gravel, that will not run to any great distance from the bank when falling from the top in slides or avalanches, jeopardizing the safety of the giants; and also a wide open and roomy pit will make it possible to operate on banks that may exceed the ordinary practicable limits of height.

Referring again to the process of *cleaning up*, which is resorted to whenever it is deemed necessary to collect the yield of the mine, some additional statements may be made.

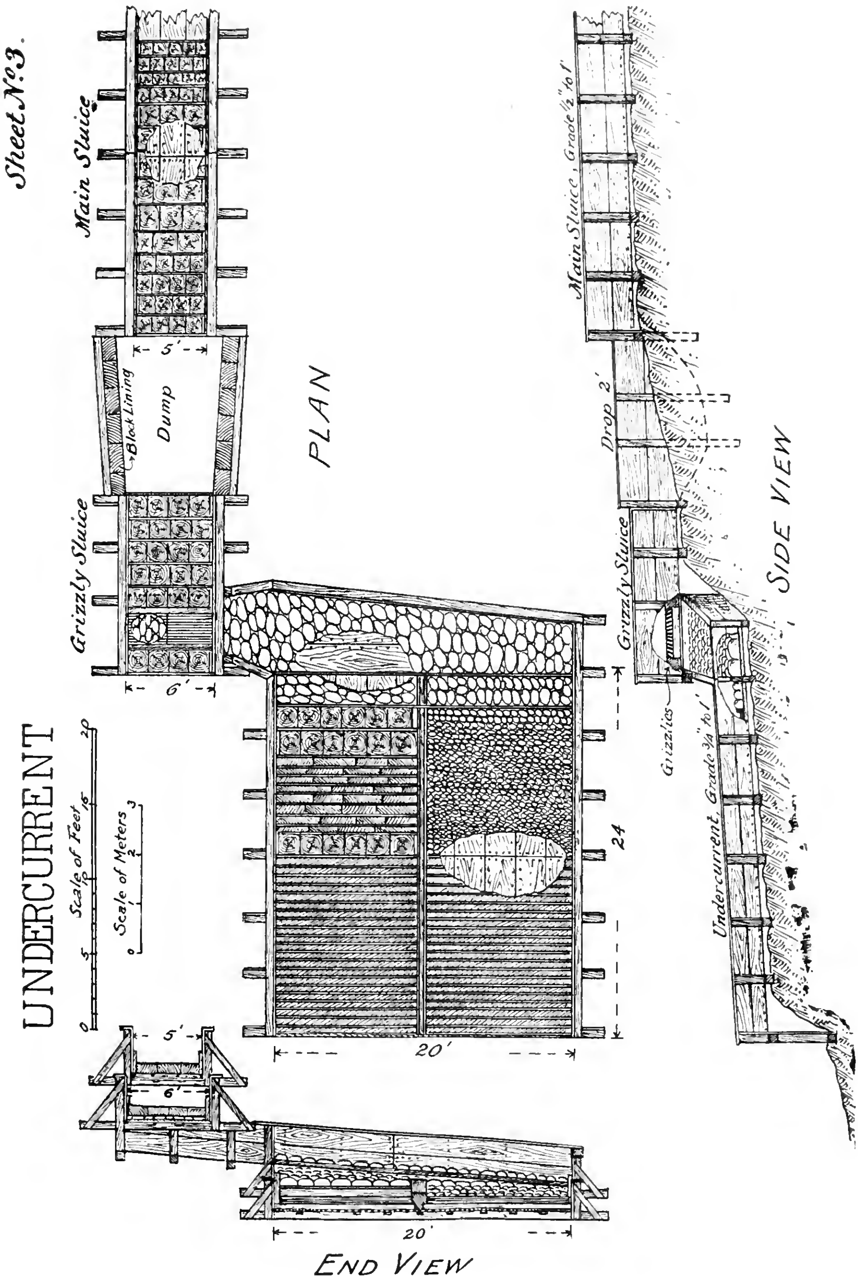
A clean-up is always required whenever the pavement is so worn by gutters that its surface becomes so uneven that it cannot be relaid to a sufficiently smooth surface without the use of additional paving material.

The cleaning-up is done by reducing the flow of the water to a very small quantity while the pavement is removing. The work is commenced at the upper end of the section to be cleaned up. As the pavement is removed, the fine material will be washed down slowly along the bared bottom of the sluice, leaving in its wake the separated gold, which is taken up in pans by scoops made for this purpose; the process is finished by panning the remaining sand from the gold, or amalgam, if quicksilver is used.

Undercurrents.

The use of these structural devices has been described before. They should be located wherever the hydraulic miner may deem them most effective. An ideal location for an undercurrent is created by placing a section of sluice 12 to 20 ft. long, and 1 ft. wider than the main sluice, at an elevation 2 ft. lower and about 10 ft. distant from the end of it. Near the lower end of this wide section of sluice, and at right angles across it, a set of steel bars, called grizzlies by the hydraulic miner, is laid. (See Sheet No. 3, and for details, Sheet No. 4.)

To prevent choking, these bars must be so placed that the space between them is wider at the bottom than at the top. Ordinary bars, 1 by 4 in., can be laid with a little care in this manner. These, to the number of from ten to twenty, are spaced


Sheet No. 3.
Main Sluice
5'
Block Lining
Dump
PLAN
Grizzly Sluice
6'
UNDERCURRENT
Scale of Feet
0 5 10 15 20
Scale of Meters
0 1 2 3
24
20'
5'
6'
20'
END VIEW
Main Sluice, Grade ½" to 1'
Drop 2'
Grizzly Sluice
Grizzlies
Undercurrent, Grade ¾" to 1'
SIDE VIEW

from 1 to 2 in. apart, according to the character of the gravel and the volume of water used in the main sluice.

Steel bars, made for the purpose, with one edge thicker than the other, make good grizzlies. The construction and location of these details are shown on Sheet No. 3 and on Sheet No. 4.

Directly under these grizzlies, and parallel to them, a box from 2 to 4 ft. wide is provided, for the purpose of leading the water and fine material that has passed down between the grizzlies on to the undercurrent proper, which should be from three to five times as wide as the main sluice, 24 to 36 ft. long, and should have about 50 per cent. more grade than the main sluice.

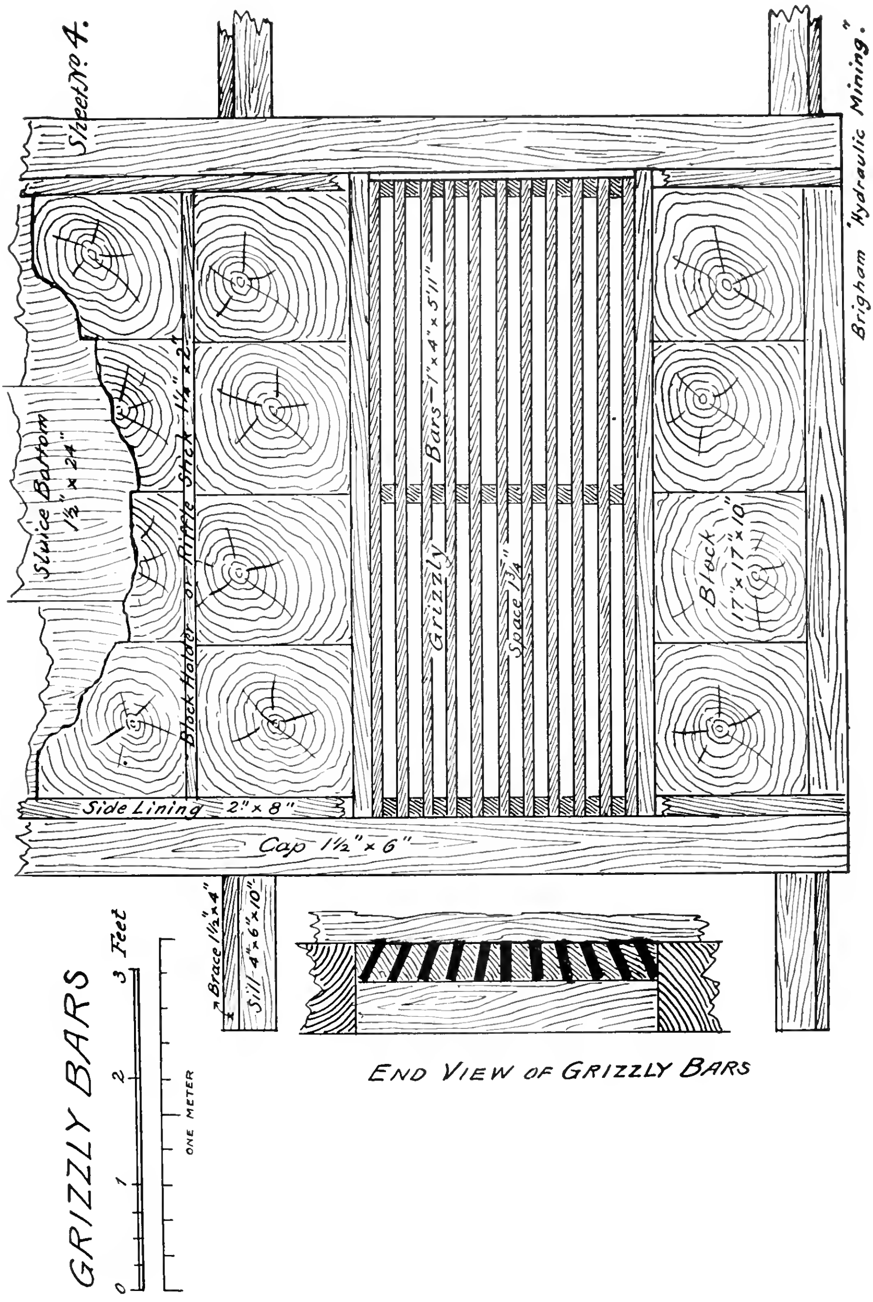
The number of grizzly bars, their distance apart and the width and grade of the undercurrent will depend upon the amount of water used in the main sluice and the character of the gravel washed; the larger the head of water and the finer the material, the greater the number of bars, and the narrower the space between them; also, the wider the undercurrent and the steeper the gradient. Where there is a very large amount of fine material, the undercurrent should have still greater width and grade than under ordinarily normal conditions All the fine material, with sufficient water to run it over the undercurrent, must be allowed to pass through the grizzlies.

The purpose of the drop in grade of 2 ft. below the main sluice is to reduce the current while passing over the bars; this will allow the fine gold to settle more readily and pass through between them, and it will also increase the life of the bars and make them last much longer than if they were placed at the end of the main sluice.

A good pavement or riffle floor for an undercurrent may be made of strips 4 in. wide, 1½ in. to 4 in. thick, lined on top with ¼-in. steel plates held by countersunk nails. These riffles should be laid on edge, spaced 1¼ in. or 1½ in. apart, and may be laid either crosswise or longitudinally. Blocks also make a very good pavement.

If the richer portion of the gravel should be very hard or cemented, it is advisable to add more undercurrents if conditions will permit. To break up the cement, a high perpendicular drop is excellent.

Should it be necessary to extend the main sluice from its lower end, by reason of the filling of the dump with tailings that finally back up into it, or for some other reason, the policy of placing an undercurrent at such locality may be questionable, as



END VIEW OF GRIZZLY BARS

it is impossible to operate one midway in a sluice without sacrificing at least 5 ft. of the grade in order to get the water and the fine material that passes over the undercurrent back into the main sluice again.

Water Storage.

The necessity of receiving or distributing reservoirs has been referred to before. They furnish facilities to regulate the head of water for the giants, and whenever it may become necessary to turn off the water at the mine, the storage will be kept immediately on tap.

The capacity for these reservoirs must be determined by the daily quantity to be used by the mine; this again depends on so many other contingencies that one must consider them all before deciding upon the practical amount of storage.

In a previous chapter the principal governing elements have been touched upon already. The constructive details are matters of engineering that must be dealt with as they come up.

Pressure Box or Penstock.

A pressure box should be built at the head of the mine pipe line.

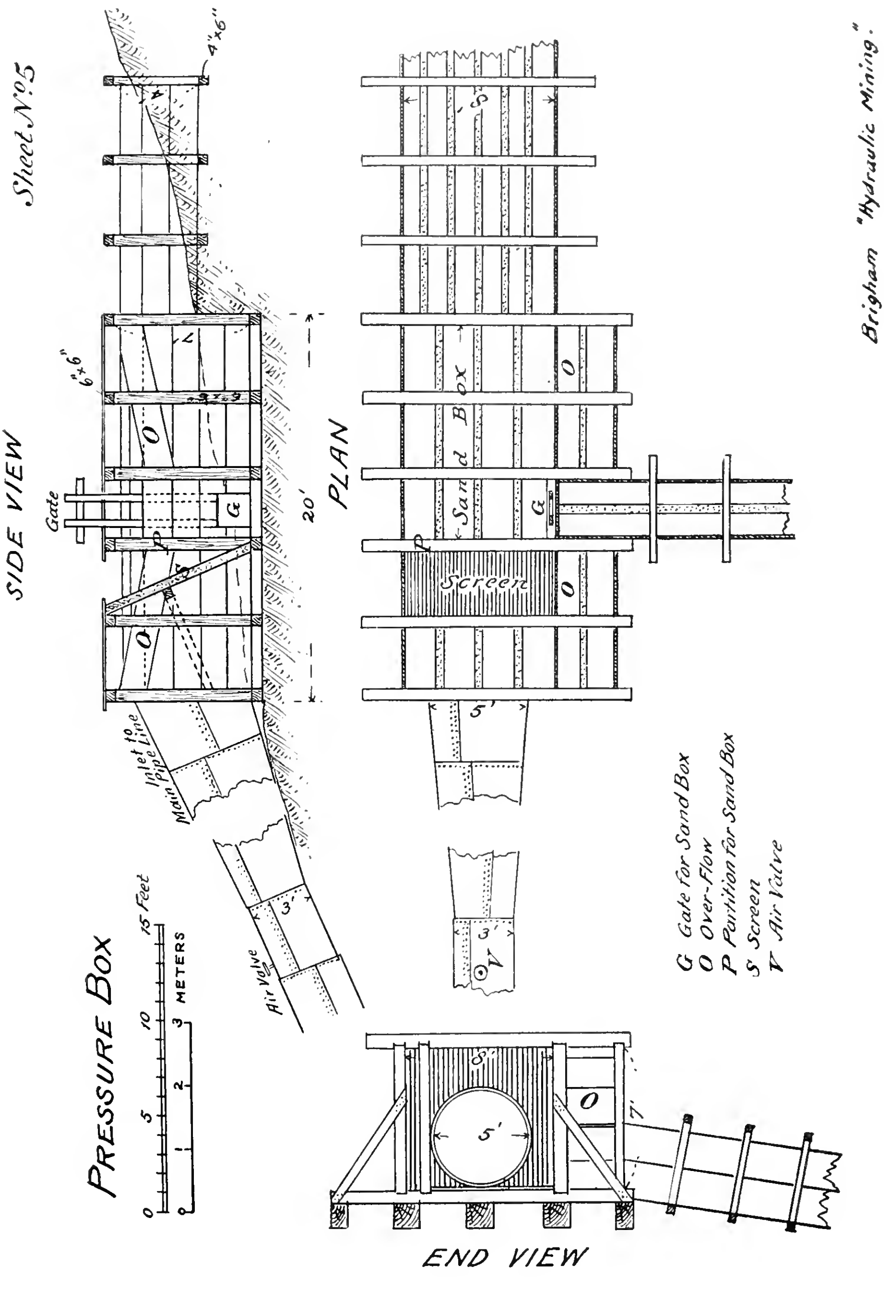
Sheet No. 5 shows a structure of this kind in plan and in view. It is more or less of a settling basin and strainer, intended to prevent sand and solids and also air from entering the pipe.

A screen is provided to catch sticks, limbs and other floating débris too large to pass through the nozzles, while a sand box of ample proportions holds the sand and other heavy material and prevents that from getting into the pipe.

A spillway is arranged on one side of the pressure box (see "*O*" on Sheet No. 5), to prevent any damage from the surplus water. This should be wide enough to take care of any possible surplus due to clogging of the screen or variation of the flow. If the water be taken out of the main ditch directly into the pressure box, and the ditch continue past it, a spillway is unnecessary.

The screen "*S*" on drawing should be fine enough to prevent anything from passing through it that may choke the nozzles, and should be so constructed that it can be readily cleared. It should also be strong enough to withstand the pressure in case it is fully choked with branches, leaves and other matter of this kind which is liable to occur during a windstorm.

The sand box should be given ample dimensions to fulfill its functions; it has a gate at the side to sluice out the sand and to


Sheet No. 5
SIDE VIEW
Gate
6"×6"
4"×6"
20'
Inlet to Main Pipe Line
Air Valve
PLAN
Sand Box
Screen
5'
3'
END VIEW
PRESSURE BOX
15 Feet
3 METERS
G Gate for Sand Box
O Over-Flow
P Partition for Sand Box
S Screen
V Air Valve
Brigham "Hydraulic Mining."

turn the water out of the pipe whenever it may be necessary to dry it.

If a larger head of water is used than can be accommodated by the sand gate, a waste-way must be provided near the bulkhead, so that the pipe may be dried quickly in case of accident, or in case there may be any necessity for changing the water suddenly.

Mine Pipe Line.

Where it is possible to bring all the water to one common and acceptable point to suit the conditions of head and locality, and in such a manner that one line may be made available for all the giants, a single line of ample capacity to convey all the required water is to be preferred.

A suitable gore or taper should be provided at the head of the pipe line, at the point of intake from the pressure box (see Sheet No. 5), and this should be of such dimensions that the water in entering the pipe is not retarded. The flatter the grade at the upper portion of the pipe line, the larger and the longer the gore that will be necessary. In any event, it should be of ample size not to create needless friction, which reduces the pressure at the giants.

The main pipe line should, if possible, be laid away from the ground to be washed, and preferably, also, on a downward grade for the entire distance, and long stretches of slack grade should be avoided, if practicable.

As the pipe approaches the vicinity where washing is to be done, suitable branches should be inserted where required until the end of the main line is reached, where a gore must be inserted, tapering to the size of the branches, or a fork provided for two branches. Each branch should have a gate or cut-off.

The branches and gates should be placed as near to the commencement of operations as practicable in order that the working area of the giants may be extended from time to time without the necessity of moving the branch pipes and gates, which is expensive and causes much delay.

If the face of the mine is very wide, and two or more giants are to be used at some distance from the main line and away from the vicinity of the other giants, it becomes advisable to make the branch of the same diameter as the main line — with a gate attached — and to extend this branch line to the neighborhood of the giants; this will eliminate much of the friction due to long reaches of the smaller branch pipes.

All turns, gates and gores should be substantially braced to withstand the pressure, and the whole line should be anchored at short intervals to prevent its creeping downhill by expansion and contraction due to changes of temperature.

Air valves of liberal area should be placed at different points along the line of the pipe wherever needed to prevent collapse from any sudden withdrawal of the water below. There should be one at every point where the grade increases materially, and one below each cut-off, if the pipe below it has considerable grade.

It is necessary to provide more than one pipe line:

First: Where the contour of the country will not permit a satisfactory site for a distributing reservoir, but where one at a lower altitude is available; or,

Second: Where a part of the water supply must be brought in a lower ditch system, too low for a satisfactory pressure and yet valuable; or,

Third: Where the deposit of gravel to be worked is so extended and isolated that a branch from the main line cannot well be utilized for it, then two or more lines will be necessary.

In the case of two available pressures at different heads, the higher pressure system should be used for the greater part of the cutting and the lower one for regulating the flow to the sluices of the gravel taken from the softer strata, or from the material that has caved under the force of the higher pressure.

Giants.

The number and size of the giants will be governed by the amount of water used, the width of the face of the gravel to be worked, the pressure of the water at the giants and the character of the gravel to be piped.

It is better to use as large giants as practicable, for much more can be accomplished with one large one than by running the same amount of water through two; also, the pay of one man is thereby saved.

The giants should be set as near the bank as safety from the falling bank will permit.

If more than one is to be utilized at one point, they must be placed so that they will command as much of the bank as possible, and be in such a position that two or more may work together advantageously in a combined attack towards one point.

Deflectors are indispensable for the larger sizes of giants. A deflector is comparable to a delicate steering apparatus; by its aid the stream may be guided from one direction towards an-

other. They are of two kinds: One consists of a short flexible coupling, inserted between the nozzle and the end of the discharge pipe; the other is a short section of pipe, a little larger than the nozzle, attached loosely to its end and projecting over the stream. Both of these deflectors turn on a gimbaled joint, free to move in any direction by an attached lever.

A light pressure against the lever in any direction bends the stream slightly; this, in turn, moves the discharge pipe, which follows it, as it were, until the stream strikes the desired point; the pressure is thereupon released, when the unmolested stream now becomes normal again and retains this direction.

Derricks and Overhead Trolleys.

If there are many large bowlders that have to be broken up in order to run them through the sluice, and if the grade of the sluice is light and the dump room scarce, it may be advisable to use overhead trolleys or derricks for handling them, if the conditions are favorable.

The derrick is an awkward and cumbersome thing to work around a hydraulic mine, especially if the bank is high and the pressure for giants light; it is necessary to have the derrick in rear of the giants, and this places it too far from its work, unless it has a very long mast and boom.

An overhead trolley is generally preferable, as this interferes little with the giants; and while its reach is restricted sidewise, it has unlimited range from the bowlder dump in the rear to the face of the mine; also, it seldom needs shifting as the working of the mine progresses.

Where there are large numbers of bowlders requiring blasting in order to dispose of them through the sluice, and where the dump room is restricted, and where the conditions are favorable for utilizing derricks or overhead trolleys, it will be found much cheaper to dispose of these bowlders in this manner rather than run them through the sluice and choke up the dump.

Hydraulic Elevators.

They may be used to good advantage at times, and in some cases the conditions are such that this is the only method by which hydraulic mining can be successfully prosecuted. In the case of valuable gravel deposits, free from quantities of large stones, pipe clay, stumps, etc., requiring hand removal, that are situated near or below the level of the surrounding country, and

with a large quantity of water under the required pressure at command, the hydraulic elevator becomes a necessity.

The elevators are placed near the head of the main sluice and at a lower elevation, depending upon the height necessary to raise the gravel.

A hydraulic elevator, so called, consists of a pipe of suitable dimensions to convey or lift the water and gravel from a pit, sunk below the bottom of the deposit to be worked, into the main sluice above. It is generally built at a small vertical angle; the top reaches into the main sluice; to its bottom in the pit is attached the elevator throat; a nozzle is placed a short distance below this, set in line with the center of the elevator pipe, and parallel to it, all for the purpose of forcing the gravel and water from the pit up into the head of the main sluice. The nozzle is connected to the main pipe line.

One or more giants may be utilized for washing the gravel from the mine into the elevator pit in a manner similar to ordinary hydraulic mining.

All stones, clay, stumps, etc., too large to pass through the throat of the elevator, must be removed before reaching the pit. The elevator must be run continuously while the mine is in operation, for the pit becomes flooded immediately, whenever the water is turned off from the elevator nozzle.

A giant under heavy pressure, placed at the lower end of the main sluice, may be used to great advantage in stacking or elevating the tailings wherever the dump room is ample in area but deficient in grade.

Any bowlders, stumps, etc., that will run through the sluice can be elevated by this process equally as well as the fine gravel.

This giant at the dump may be utilized at any time, whether the sluice be running or not, whenever there is a surplus of water, or whenever it may be turned off from the mine. Either the hydraulic elevator or the giant at the dump creates a larger grade for the main sluice, a matter that has been referred to before.

If there should be a depression in the bedrock of the mine below the grade of the sluice, or if the sluice as it extends ahead into the mine should pass over valuable deposits, this gravel could be elevated and forced up into the sluice in a manner similar to the elevation of the tailings at the dump.

This, of course, should be done after the top has been worked down to the sluice grade.

The depth from which gravel can be elevated by this process

depends upon the giant pressure. With a pressure of 300 ft. there should be no difficulty in forcing it up from a depth of 15 ft. or more.

Ditches.

The old hydraulic miner became an expert in the location and design of a ditch to convey the necessary water to meet his requirements. He was remarkably successful in overcoming difficulties of topography, and mechanical difficulties as well, and he usually overcame them without scientific instruments or scientific formulæ, guided alone by his keen sense of the practical and by his ever-resourceful mind.

Many of the old mining ditches in evidence to-day bear testimony to his skill, to his perseverance and to his audacity. Mining and ditch building were almost synonymous terms in California, and on the experience of the hydraulic miner much that we know to-day of the behavior of the flow of water in ditches and in pipes has been based. The investigations of Hamilton Smith are considered of great importance to-day and they have added no inconsiderable knowledge to what was at his time a rather barren field.

The irrigator has taken the ditch and flume in hand recently, but with him it is not so much a matter of overcoming physical obstacles as it is a problem involving a sufficiency of grade, volume and flow in the valleys, where the adequacy of the gradient becomes a subject of more serious consideration.

A ditch must convey the required quantity of water. To do so, it must have capacity and grade, or fall. These elements are interdependent and need to be placed in proper relation. The flow through a given cross-section of the ditch must be of a speed to permit the number of miner's inches to pass and yet not too swift to erode the material into which the ditch is cut. This matter has been referred to before.

While the hydraulic miner knew by experience how to arrange his fall, his grade and size, the engineer of to-day may have recourse to the elaborate formulæ that have been devised to help him. The Kutter formula and its modification by more recent hydraulicians, particularly Californians, furnishes him with the means to design ditches of proper capacity and gradient in any material. A few practical hints, however, by an old hydraulic miner will not be amiss.

In laying out the line of the ditch care should be taken to avoid any abrupt turn, unless this be absolutely unavoidable

In making a turn around a sharp point, the line should be carried into the hill somewhat, in order to insure a strong embankment.

In turning around such points, it may be desirable to raise the grade for the top of the ditch to correspond to the height of the permanent roadway along the ditch, thus leaving a solid embankment to the full height of the roadway.

The slope of the bank will be governed by the character of the ground along its course; the upper bank should be sloped back far enough so that the current cannot undermine it and cause slides or caves; accidents of this kind will occur during the rainy or flush water season, if they occur at all, causing bad breaks, and entailing great expense, loss of water and delay while repairing.

All trees liable to fall and damage the ditch ought to be cleared away. The surface below the ditch should be stripped of all brush, leaves, débris, etc., before commencing the excavation, in order that the material taken from the ditch and deposited on its lower bank may unite firmly with the undisturbed ground, making a solid and permanent bank after settlement, which will permit the miner to raise the water in the ditch later on, thereby increasing the capacity considerably.

After the ditch is excavated, the lower bank should be leveled down in such a manner as to leave a good roadway; care is to be taken that the elevation of this roadway be considerably above the grade line as a protection against breaks, when, for any reason, small obstructions should occur that may back the water slightly above the grade.

Flumes along the line of the ditch should be avoided as much as practicable, particularly if the water supply be partially or wholly cut off during the dry season; at such time the lumber will shrink and crack, damaging it more or less, and shortening its life considerably.

Where conditions are favorable, a double wall may be built, filled between its two faces with clay or suitable dirt, by which a permanent bank is secured; and while this will increase the original cost, the extra expense may be justifiable.

Even in quite hard bedrock, it may be perfectly reasonable to do considerable blasting in order to avoid a flume and to insure a permanent ditch.

The Flume.

This is so well known and has been used so extensively in

California that it seems almost needless to refer to it here. But however that may be, practice is gained by contact and experience, and errors are frequently committed in the earlier history of a work that might have been avoided if it had been possible to impart some of the results of those who had passed through similar experiences themselves.

The author in his long contact with many different types of flumes had under his immediate charge for several years one which so completely answered the requirements that it seems justifiable to call attention to it here.

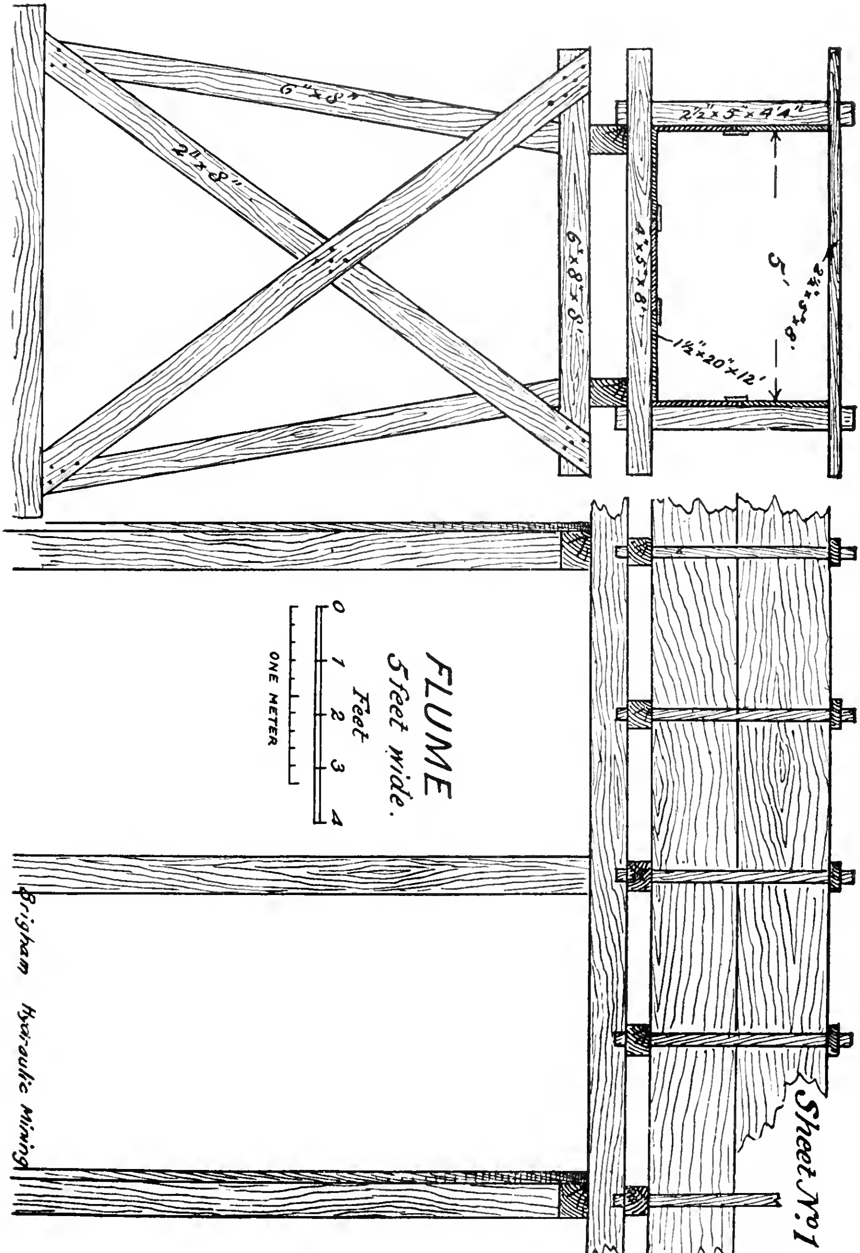
This flume was some 8 miles long, 4 ft. wide, 38 in. high, and lay on a steep hillside on a narrow bench that was graded just enough to afford a resting place for the inside of the flume; the outer side was held by props from the bank. This was the condition for nearly all of its length.

It was built of unselected yellow pine lumber, with 1½-in. boards for bottoms and sides, 4 by 5 in. bottom ties, 6 ft. long; 2 by 5 in. top ties, 6 ft. long; and 2 by 4 in. posts, or standards, 4 ft. long; no braces; bottom and top ties mortised for the posts, which were unframed. (See Sheet No. 1, to which reference will be made frequently.)

This flume was in constant use for thirty years. The portion that rested but partially on the ground was kept in repair at small expense, and its use could have been continued at a nominal expense for several years longer had the market for its water still existed. Aside from renewals due to accidental causes, practically all of the flume that rested on the ground was still the original construction after its long use, and the greater part of it had not required the replacement of as much as a bottom tie in all that time.

It shows the possibility of a simple construction that one might not have ventured upon, preferring some more elaborate foundation at almost prohibitive cost. The risk proved the perfect practicability in the long and useful life of this simple flume, and it teaches us to place faith in the somewhat bolder design, if the best judgment has been brought forward in its location and alignment, and in the study of the topography to which the structure must be adapted.

A flume may be laid on an excavated bench on its sills, projecting over the bank more or less, in some manner as just described, or it may be erected on a partial trestle work for the support of the outer side. Gulches or deep ravines must be crossed on trestle bridges, as the illustration shows it. These


6"x8"
2"x8"
2½"x5"x4'4"
6"x8"x8'
4"x5"x8'
5'
2½"x5"x8'
1½"x20"x12'
FLUME
5 feet wide.
0 1 2 3 4
Feet
ONE METER
Sheet No 1
Brigham Hydraulic Mining

may often become very formidable structures if there is no other alternative in making the crossing.

Short sections of flume should have the same area as the ditch, but long sections may be somewhat smaller, owing to the decreased friction of the water; it is questionable, however, whether a change of size is always justifiable, unless the reach of flume has considerable length, for the reason that it is inconvenient to keep various varieties and sizes of lumber in stock for repairs. If there is considerable repairing to be done, it is better to have only a few different sizes, thereby reducing the stock of lumber that would be required otherwise. It may be quite practicable to plan the size of the flume in such a way that the same sizes may answer for both sides and bottoms.

The size of the material for a conventional flume of the type under discussion may be obtained from the following general description:

Lumber of 1½ in. is very suitable for the bottom boards and the sides, where the depth of water does not exceed 3 ft.; if much deeper, 2-in. boards will be necessary, especially for the bottom.

For sills, or bottom ties, 4 by 5 in. pieces will answer for flumes up to a width of 4 ft. containing a 3-ft. depth of water; for a wider flume, 4 by 6 in. may become necessary; for a flume 10 ft. wide, with a 4-ft. depth of water, it will be well to make them 6 by 6.

For the top ties, or caps, take 2 by 5 in. pieces for a 5-ft. flume; 2½ by 6 in. will answer for one of 8 ft. where there is little snow. If much snow has to be provided against, they must be correspondingly heavier.

For standards, or uprights, use 2 by 4 in. lumber for a 2½-ft. depth of water; 2½ by 5 in. for a 3½-ft. depth; and 3 by 6 in. for water 4½ ft. deep. These sizes are all desirable as they need no framing, the bottom and top ties being mortised through. The standards, cut to proper length, are driven firmly into the bottom tie, which acts as a brace, eliminating the ordinary diagonal brace necessary where the standard is set into a gain in the top of the sill. Another advantage over the latter is, that as the flume becomes old and weak from decay, it is much more stable and also more easily repaired, and it will last longer than the flume in which the side ties are gained into the sills and caps.

In order to prevent the clear water from running over the sides of the flume abrupt turns are to be avoided as far as that can be done and as explained heretofore under "Sluices," where the object in view was that of preventing the sluice from choking.

Where a flume joins the ditch, especially at the upper end of the flume, a small gore should be inserted into one box-length, making it bell mouthed. This will prevent the water from backing up into the ditch, and it will have a tendency to prevent lumber, sticks and floatage from catching across its head. A similar case in the lower end of the flume, having a swift current, will prevent the ditch immediately below from undue erosion.

Waste-Ways.

Waste-ways for turning the water out of the ditch in case of accidents, oversupply from rains or melting snow, or other causes must be provided at intervals along the ditch. They should be placed at points where the escape of the waste water will not result in cutting away the ground below the ditch and endanger its safety.

If the ditch is in a cold country where large amounts of snow will collect in it faster than they can be run through it, or where snow is likely to fill up the ditch when the water is not running, which would have to be sluiced out later, the waste-ways should be at frequent intervals, for it is necessary to get the water out quickly and in time before they become clogged up and break.

All waste-ways should be so constructed that the entire flow can be quickly turned out, and they should be so located that the water may escape without endangering any part of the ditch. Some provision should also be made to keep the freshet water from ravines out of the ditch; if it be impracticable to place these waste-ways at or near the ravines, in order to use them for that purpose, other means must be found to prevent this serious inflow.

Concluding Remarks.

These notes on the subject of hydraulic mining have been collated not to furnish any text or data for the student, but rather to give the practical engineer who may come in contact with this sort of work some idea of the main guiding principles underlying the successful installation of a plant of this kind.

It has not been the idea to go into the processes and results of hydraulic mining proper, for that would require more time and space than the author had at his disposal; nor is it possible to give sufficient information of an extensive method that must be learned by daily contact to enable one to follow it as a profession.

This paper has been written for engineers and for those who

may follow hydraulic mining, with the end in view of placing certain practical knowledge at the immediate disposal of those who may be looking for it. This the author has attempted to do with some effort at system, although it will be admitted that he has frequently broken from one subject into another as these subjects become interlaced. However, it is hoped that he has made himself clear.

The illustrations that accompany this paper were made in detail to show without too much explanation the main constructions with which the hydraulic miner has to deal.

They consist of:

Sheet No. 1. Side elevation and section of a flume.

Sheet No. 2. Section through a sluice, showing the block system and the riffles.

Sheet No. 3. Plan and views of an undercurrent, showing constructive details.

Sheet No. 4. Plan and section of a set of grizzly bars showing the arrangement and location in the sluice.

Sheet No. 5. Plan and views of a penstock or pressure-box, showing constructive details.

Other Uses of the Hydraulic Method.

Hydraulic mining embraces two eminent branches of engineering, hydraulic or civil engineering, and mining engineering. Its field of separation has been confined to the mountains and its sole object has been the recovery of gold. Where nature has covered and hidden treasures by cyclopean power, man has brought them to light by the use of other herculean forces that he has been able to harness and to utilize according to his will.

But there is another field wherein the unfortunate miner may be dropped, that is, as far as gold seeking is concerned, and where the civil engineer may usurp his place, and that is in hydraulic excavations. Furnish water under sufficient pressure and favorable conditions and the process described will enable ius to remove mountains.

There are very great opportunities for the hydraulic method in the construction of earth dams and levees, in making the cuts and fills for railway embankments and in filling depressions by removing material from one locality and transporting it to another.

Where the conditions are favorable, an earth dam can be built more substantially and more economically by this method than by any other.

Millions of cubic yards of gravel have been displaced in California by hydraulic process, and the gold extracted therefrom, at a cost of less than one cent per cu. yard, aside from the expense of furnishing the water.

In the building of dams it is an open question whether a greater expense incurred by this method of depositing the material may not be justified, by reason of the greater security of a structure built up in this way. Its solid compactness and greater stability hold out every inducement to make use of hydraulic processes. This may be said with equal assurance of other embankments, because the settlement of such structures after completion by this method is practically *nil*.

Most localities where dams are contemplated will have a sufficient available supply of water for such purpose if it is pumped and the same water used continuously.

Where a sufficient pressure is obtainable, a hydraulic elevator may be installed to lift the earth from the reservoir bottom to the height of the lower portions of the embankment, leaving but a comparatively small part of the upper work to be completed by another process.

In the building of levees the hydraulic method is particularly well adapted, because it is not only economical to use it, but it will also make an extremely stable and solid embankment, one that cannot be made equally stout and firm by any other process. The conditions are generally favorable to utilize it, too.

It requires some skill and experience to obtain the best there is in hydraulic work to build dikes and levees, but in the consideration of the great amount of such work to be done, there is every reason why the civil engineer should acquire a practical knowledge of this useful method.

The author may have more to say on this particular part of the subject at some future time.

DISCUSSION.

Mr. W. W. Waggoner (*by letter*). — It has been a pleasure to read the paper upon hydraulic mining by Mr. H. A. Brigham, Member Technical Society. The author is one of our ablest hydraulic miners; he has given many valuable hints to those who may use this means of moving material, not to be found in the textbooks. The paper should be preserved as a valuable work of reference.

Gravel mining was the great industry that brought California into prominence. During its development it brought

forth many able hydraulic engineers, who invented methods and appliances that have been found valuable in other branches of constructive work. A phase of hydraulic mining is now used on river banks to prepare them for revetment, for railway embankments and for dam building. By this means a watertight bulkhead may be built to any practicable height.

The use of riveted wrought-iron pipe, although first used to displace canvas hose, has now a wide application in conveying fluids.

The rock-fill dam is another novel method of dam construction that is now recognized as standard. It is to be regretted that the name of the engineer who developed this method of moving material is lost to history. His work stands out more boldly when it is considered that gold was discovered in 1848. The year 1849 saw the first influx of gold-seekers. In 1855 our reliant pioneers had found the best gold deposits and had recognized the needs of the water supply. One of the earliest companies, with French capital, under the management of Benoit Fauchere, now spelled "Faucherie," built the dam at the locality known as French Lake, during the time from 1855 to 1858. It is probably the oldest structure of its kind in the State. In the primitive condition of the times (without roadways, without Portland cement), the designer broke away from all precedent and built his rock-filled dam 68 ft. high, with a water slope of one on one, and a downstream slope of ten on one. The stone on its faces was carefully laid. To make it watertight, a plank skin was used. There were no sawmills, but the planks were got out by whipsawing; they were fastened to the ribbing by tree-nails. On the flat slope the water holds the planking in place with the same force that would take it away. This plank face has been replaced several times. With a future impervious concrete face it will stand for centuries as a monument to its unknown designer who broke away from all precedent and builded better than he knew. So must we depart from the conventional in order to solve the problem presented by the author.

It is with some reluctance that I attempt the task assigned me by our Society, — to open a discussion upon the problem of the future recovery of the $90 000 000 of treasure locked up within the great gravel deposits.

It is now twenty-four years since the Sawyer decision was rendered in the celebrated suit entitled Edwards Woodruff *vs.* North Bloomfield Gravel Mining Company et al., which resulted

in the closing down of the hydraulic mines. Since that date but little has been done towards the solution of the problem, and but little could be done on account of the ill feeling that such litigation and its attending losses are sure to produce. The lines of Rossiter W. Raymond in describing an apex mine lawsuit are very applicable:

> "No matter now which party lost —
> It took the mine to pay the cost;
> And all the famous men who saw,
> Beheld with mingled pride and awe
> What science breeds when crossed with law."

The mine has been doomed already, and it looks very much as if the farm would have to go, too.

Most of the men who were prominent in the hydraulic mining industry have passed away since. This is also largely true of the prominent valley men who took part in the dispute. The men who will meet this problem are of the succeeding generation, and they should be able to enter upon its solution without the rancor that injected itself into the past attempts. The problem is local; it is of no use to go to distant parts of the world to obtain talent and to search for men to do something concerning which they have no experience and little knowledge of the principles applied. On the contrary, it will result in a definite plan if the engineers of the different interests get together as a jury, as it were, and come to an agreement. It is fitting that some attempt should be made towards the solution of this problem by the Technical Society; its members are prominent in the State, and some of them who took part in the litigation could now lend great aid, with their riper experience, in the consummation of a plan that would mean so much to the welfare of the Country.

The problem, as far as the mines are concerned, is comparatively simple, and were it not for the complications already existing in the valley, that resulted from the operations of the mines during the last half century, a matter which will be dwelt upon later on, the solution would not be difficult.

After the injunctions, and when the mine owners became aware that if they were to operate their mines extensively they would have to impound their tailings, it was recognized that the cost of restraint would be a serious addition to their operative expenses. For that reason, with various arguments, attempt has been made to get the general government to bear a part of the expense, but so far without avail. To-day the mines are

closed down, the companies are disorganized, the miners are scattered or in other pursuits, much of the water that was used for mining is diverted to other industries at a better profit, and the mines themselves, even to the pits in many cases, are being reforested with a thick growth of trees. To resume hydraulic mining operations is a question of dollars and cents. The deposits to be worked are all known; so are approximately their values. If they are worked, it must be with the distinct understanding that their débris is impounded. For many mines this will be a permanent injunction, inasmuch as they could not work at present prices and with the demand for water. For those that would pay, storage would have to be provided. This is a question of capacity, with due regard for the "facilities of dump" that our author dwells upon, and in addition, one of location and of the effect of débris upon existing interests.

In the last twenty-four years there has been a wonderful development in other lines. The use of electric power, irrigation and the dredge mining industry have come to the front. These can be developed to a marked extent in the area adjacent to and available for the impounding of débris, at a reasonable cost and as part of the plan for the resumption of mining operations, thereby reducing the cost to the mines.

Take the Yuba River, for example. On its watershed are the greatest gravel deposits that have been the scenes of the largest mining operations. This river is at present, without any mining, the worst offender as far as deteriorating the navigable rivers is concerned. Dams can be built upon that river at many practicable sites. They should be of stone and, needless to say, of a permanent character. The type may be (where a proper foundation is available) that of a masonry dam for the storage of water, or it may be formed by blasting down great masses of rock from the adjoining cliffs and throwing them into the canyon, forming a bar as it were, and thereby raising the plane of the river. The winter floods will take a portion of it away each season and deposit the rock farther down stream. But working upon the principle by which the rivers were filled by the early mining, that is, that of dumping more rock into them than the floods could carry away, the dam can be raised to a great height. The blasts may be so arranged that when the final height has been attained a wasteway may be built that will carry any coming flood around the dam, thereby insuring the stability of the structure for all time.

From the crest of the dam the water — amounting at present in the low season to 500 second-feet — may be taken around the hills to an available site for the installation of a large electric power plant, and thence led around the foothills of Yuba County for irrigation purposes. By taking the entire low-water flow out of the river, eight miles of its channel will become available for dredging purposes for a long period of each year. This ground is estimated to have a value of $20 000 000. Future hydraulic mining operations will require additional storage of the flood waters and thereby add to the material wealth. The sites for such dams are in mountain canyons that have no particular value at present, and they can be filled to a great depth by the outlined methods. If these dams had been built years ago much of the débris now in the lower rivers would have been kept out of them and would lie away from its present resting place. Such structures would also tend to impound much of the natural erosion of the mountains that now reaches the rivers below. Were such works to be constructed, capital would have to be secured to reopen the mines, rebuild the water-supply systems and to bear a share of the expense of dam building. It is not conducive to the investment of new capital in this enterprise if the present valley conditions are once fully recognized.

It should not be overlooked that such an investment will be constantly harassed by certain interests, until relief is brought to the valley from the accumulations of the old débris in the non-navigable streams, for which this new capital could not be held responsible in any wise. The investors will naturally consider it enough of a burden to impound their own débris and that of natural erosion.

Now for the valley phase of the problem. The Yuba River, after it leaves the mountains, spreads out to a width of nearly three miles between the levees, with a grade of from 3.5 to 19 ft. per mile. It is filled with débris from the past operations of the mines, ranging from fine silt to cobblestones. It is known to be 31 ft. deep at its mouth, near Marysville, and it is estimated to be 100 ft. deep at a locality known as the Barrier Sites, 15 miles upstream. In one place the débris is 14 ft. above the adjacent land. This deposit has been variously estimated by different engineers. It was placed at 700 000 000 cubic yards by those who knew the quantities sent down. Over this deposit great floods flow every few years. I have seen the Yuba at flood time flowing to the width of one fourth of a mile, 10 ft. deep in the

shallow water, with a velocity of 14 ft. per second in slack water.'

When the mines were in operation, twenty-four years ago, the water in flood spread over the entire area and only the fine silt was carried to the mouth; the gravel was deposited higher upstream. Since the mines have been closed and the supply of mining débris cut off, the river has been eroding the gravel in the mountain canyons until they are now practically clean of débris, and it has redeposited this upon the great layers. Now, and for some years past, the floods have been attacking the deposit by cutting deep channels; the material so eroded is carried into the Feather River; at the same time gravel is brought down from its upper reaches and deposited below. From all appearances the cobbles will also be represented. This is one of Nature's laws of restoring the base level after the period of artificial filling ceases. From a mining standpoint it is a magnificent example of ground sluicing. The effects are disastrous. The heavy material deposited upon the bed of the Feather River, with only a grade of about 1.5 ft. per mile, causes a rise in the water-table of the surrounding country. From this cause alone thousands of acres of valuable land are destroyed in Sutter County by seepage water. It causes the levees to be raised higher each year. To illustrate conditions, let us take the high-water records at Marysville. During the period of extensive mining, and later during the illicit stage, only in one instance, that of December 24, 1884, did the high water reach 17 ft. 1 in. Since then, under channel building conditions, we have the following flood heights upon the Yuba River:

May 27, 1895	15 ft.	10 in.
January 18, 1896	18 ft.	5 in.
February 6, 1897	16 ft.	3 in.
February 7, 1898	12 ft.	1 in.
March 25, 1899	18 ft.	5 in.
January 3, 1900	18 ft.	0 in.
February 2, 1901	19 ft.	0 in.
February 26, 1902	16 ft.	11 in.
March 31, 1903	19 ft.	4 in.
February 25, 1904	20 ft.	0 in.
January 23, 1905	17 ft.	9 in.
January 19, 1906	21 ft.	9 in.
February 2, 1907	22 ft.	4 in.

On March 19, 1907, the gage read 24 ft. 4 in., and a much higher record would have been made had not a levee broken on

the Sutter side. The above shows a deplorable condition in what should be a prosperous farming region. What is to be done with the deposits of débris in the non-navigable streams, adjacent to the navigable rivers, lies within the province of the engineers representing the valley interests. They have serious problems to solve in preventing the overflow of the land. Efforts have been made to get government aid, but so far without success, for the government limits its work to maintaining low-water navigation. What is wanted now by all concerned is a cure, not palliative treatment.

It must be evident to all that a solution of the river problem is not possible without taking care of the débris now adjacent to the navigable rivers. The débris may be treated in one of two ways.

First, by keeping it out of the rivers; this will be complying physically with the intent of the decisions of the courts, and if works were built with a liberal factor of safety, the mines could operate without further restriction. The condition of the rivers would be improving while the other features of the valley problem were receiving attention.

Second, by finding a new resting place for the débris.

The various factors that make up the " facilities for a dump," as in mining, have to be considered. From a mining viewpoint, hundreds of millions of cubic yards of material will have to be handled. The work may be done either by channel building and sending the material handicapped with the decreasing river grades to the bays, or by dredging and stacking the material upon adjacent land and destroying this with the sand and the gravel. It occurs to a miner that the cheapest method must be that of keeping the material out of the rivers altogether. By so doing a " community of interests " will exist between the farmer and the miner, and stronger reasons may be given why the government should aid in the work.

It must be recognized that the débris problem is one that, in time, will affect all the rivers of the country. One hundred years from now there may be 250 000 000 people within the United States. Much of the mountain land now covered with timber will be, of necessity, cleared and in cultivation. The rains will erode the soil as now, and the flow of mud and sand will be increased. The river channels that are now, according to reports, deteriorating, will be more deeply filled and navigation largely destroyed. Already investigations are being made by the federal government, looking to the conservation of natural

resources. It will be found that the conservation of the soil by keeping it on the land and not in the rivers will be profitable both for the individual and the government. The work should begin now, and California offers peculiar advantages for the undertaking and should be the scene of the first work.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by January 15, 1909, for publication in a subsequent number of the JOURNAL.]

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THE RECTANGULAR SYSTEM OF SURVEYING.

BY W. A. TRUESDELL, HONORARY MEMBER OF THE CIVIL ENGINEERS' SOCIETY OF ST. PAUL.

[Read before the Society October 12, 1908.]

OVER four years ago a paper on this subject was read before this society and afterwards printed in the ASSOCIATION JOURNAL (April, 1904). Unavoidably it was somewhat brief and incomplete and contained opinions that will bear modification. The true origin of the rectangular system was not considered. Some of the men connected with the earliest surveys were given undue prominence, while others did not receive sufficient mention. This paper is offered as a supplement or revised edition to the first one, with the hope that it will give additional information on a subject that was never generally well understood.

No writer has ever given this subject any attention at length. There have been many allusions to it in historical works and writings, but in every instance the origin was either unknown or shrouded in mystery. Some eight or ten different persons have been credited with the authorship of the system, from De Witte, a Dutch surveyor, to President Washington, who in reality was very much opposed to the ordinance of 1785. Professor Davies taught that Colonel Mansfield originated and adopted the system in 1802 expressly for the wild lands of the West, and another writer has found the origin in the far-off Roman Empire.

The origin and history of the rectangular system of surveying is an open book with no mystery about it. No man in particular

was the originator. It was the result of growth and development founded on the fundamental principles of self government, formulated into a law after a long and acrimonious sectional controversy and put into practice because necessity required it.

Any one who attempts to investigate this subject will be greatly surprised at the scarcity of material. The government records and archives contain nothing whatever. No information can be obtained from the General Land Office, or from those states where the records of the earliest surveys are deposited. There is probably not a letter that Jared Mansfield ever wrote while surveyor-general now in print. There is a mass of papers, letters and other documents, especially the papers of the Old Congress, all in manuscript, now in the vaults at Washington, but it is inaccessible. Until this is unearthed and placed in the hands of a capable person a complete and correct history of the rectangular system cannot be written.

The Ordinance of 1785 in the Continental Congress.

The record commences in 1784. On May 7 of that year an "ordinance for ascertaining the mode of locating and disposal of lands in the western territory, and for other purposes," was reported by a committee and read for a first time. This committee was, Thomas Jefferson, of Virginia; Hugh Williamson, of North Carolina; David Howell, of Rhode Island; Elbridge Gerry of Massachusetts, and Jacob Read, of South Carolina.

On May 18, the report was called for but not considered, only one state voting aye.

About this date Jefferson was commissioned by Congress as minister plenipotentiary to assist Franklin and Adams in negotiating treaties of commerce with European countries. He joined his associates in Paris the following July and had nothing further to do with the legislation of this law. The ordinance was not considered again until the next March, when Congress was in session in New York.

On March 16, 1785, the report of Jefferson's committee was taken up for a second reading and ordered to be recommitted to a committee composed of one member from each state. This committee was made up of Long, King, Howell, Johnson, Livingston, Stewart, Gardner, Henry, Grayson, Bull, Williamson and Houston.

On April 14, Grayson, of Virginia, submitted for this committee a newly written report entitled, "An ordinance for ascer-

taining the mode of disposing of lands in the western territory," which was ordered read for a first time. When first submitted, it provided among other things for the division of land into townships seven miles square. This ordinance was brought up and considered almost daily from April 20 to May 3, when it was amended from "seven miles square" to "six miles square." The amendment was made by Grayson, and seconded by Monroe of the same state. Twelve states voted, all in favor except New York. The ordinance was then considered on six different days until May 20, when it was read for a third time and passed. The final vote is not given. (Journal of Congress, Volume 4.)

This is the recorded history of the famous ordinance of 1785. Its primary object was the raising of revenue, yet so many were the conflicting sectional opinions between the New England and the Virginia members, and so great was the inertness of Congress, that it required a year to enact the measure into a law. It was passed only after great effort, and was then a result of compromises. Grayson, writing to Timothy Pickering, says: "Since I arrived here I have been busily engaged in assisting about passing an ordinance for the disposal of territory. I think there has been as much said and written about it as would fill forty volumes and yet we seem far from a conclusion." (Grayson to Pickering, April 27, 1785.)

The ordinance of 1785 was the origin by law of the rectangular system of public land surveying and the first legislation on the subject. Nothing officially is known beyond this act. The records show that Jefferson at first and Grayson, later, were the most active in its formulation, but the many different interests that developed during its consideration, and how they were finally reconciled and compromised, the numerous arguments that were urged for and against the measure, are now difficult to determine.

The ordinance reported May 7, 1784, was most thoroughly prepared and written wholly by Jefferson's own hand. There is reason to believe that he was the principal, if not the sole author. It has always been believed, but erroneously, that this was the first suggestion ever made to divide the wild lands of the West into square forms. The suggestion in itself has been considered a wonderful creative idea, and Jefferson has been credited with this first stage of the system which was finally made a law. Although he was a man who always had ideas and opinions of his own, he could not have been ignorant of General Putnam's letter to Washington in the previous year or of Hutchins' plan of

frontier settlements in 1764. Furthermore, unlike all other Virginians, he was a great admirer of the New England towns and had said that "they had proved themselves the wisest invention ever devised by man for the perfect exercise of self-government and for its preservation." He had repeatedly urged the same system in Virginia.

There is no unusually great invention or conception in the square form provision of the ordinance, neither is there any necessity of speculating about its origin. The physical features of the western country, wild, vacant and prairie, would naturally suggest such a plan. No matter how irregular any subdivision might be inaugurated, it would eventually work itself into regularity with latitudinal and longitudinal boundaries. It will be shown later that this was actually done in southern Vermont, thirty-five years before the land ordinance was written.

That part of Jefferson's report which related to the surveys contained the following provisions:

1. The territory to be divided into hundreds of ten geographical miles square, each mile containing 6 086 feet, by lines to be run and marked due north and south, and others crossing these at right angles. The hundreds to be subdivided into lots one mile square, each of 850 acres, by marked lines running in a like manner north and south, and others crossing them at right angles.

2. Surveyors, to be appointed by Congress or a committee of the states, to divide these lands into hundreds under direction of the register. Lines to be measured with a chain and plainly marked by chops or marks on trees and exactly described on a plat, whereon shall be noted in their proper distances all water courses, mountains and other remarkable and permanent things over or near which such lines shall pass.

3. Nine townships to be assigned to each surveyor, who shall divide each hundred in his district into lots. Lines of the lots shall be distinguished by a single mark on a tree, those of a hundred by three marks.

4. Describes the manner of numbering the lots from one to one hundred.

5. Surveyors to pay due and constant attention to the variation of the magnetic meridian, marking on every plat what was the variation at the time of running the lines thereon.

6. A register to be appointed by Congress for each state, to keep an office in, and to reside within, the state, to receive all plats semi-annually and to deliver them to the secretary of

Congress, he to have power to suspend any surveyor for cause.

In the ten miles square hundred we can see the trend of Jefferson's ideas. He was committed to the decimal system. He had recently proposed the division of the entire Northwest territory into ten states of square forms, either one hundred or one hundred and fifty miles in size, and had planned and secured the adoption of our present system of coinage.

The report submitted on April 14, 1785, was written by Grayson, of Virginia. It was made up by him from the many conflicting opinions and was urged through Congress by his effort. In a great measure it was copied from Jefferson's report of the previous year, though with some changes, the principal ones being the seven miles square township and the appointment of a geographer. Grayson uses the words "township" and "section" for the first time. Jefferson's hundreds were to be divided into lots on the ground, and the method of numbering through the hundred was specified. Grayson's townships were divided into sections on paper only, without any described manner of numbering. The manner of running the lines and marking on trees was the same in both ordinances, and very deficient. It is evident that so far no practical surveyor had been consulted.

Those provisions which related specially to the surveys were very small portions of the ordinance. Each one described the country to be surveyed and contained much more which is irrelevant here, covering in detail the sale of the land and how it should be paid for; designating the officers who should transact that part of the business; also several provisions about reserving certain lands and moneys for payment of officers' and soldiers' claims; for school funds and for other purposes; transmitting township plats; reserving a part of all gold, silver, lead and copper mines; making out and delivering deeds and the forms of deeds.

The ordinance as finally passed differed somewhat, through amendments, from the one first submitted. The townships are six miles square, lots are used instead of sections and there are no 320-acre divisions. There is no subdivision into lots on the ground, and no specified manner of numbering the lots. The same method of running and marking the lines is prescribed, except that in running the external lines of a township the surveyors shall, at the interval of every mile, mark the corners of the lots which are adjacent, always designating the same in a different

manner from those of the township. Every alternate township to be sold by lots, all others to be sold entire.

From the time this ordinance was recommitted on March 16, until its final passage, a period of two months, the Eastern people were arrayed against the Southern on almost every provision of the measure. In fact, they were contending for the extension of their favorite principle of self-government, and it was only by meeting each other half way in a spirit of compromise that any agreement was possible.

That part of the ordinance which provides for the division of land into square form, and which is, in fact, the whole substance of the rectangular system of surveying, was due entirely to the determined stand taken by the delegates from New England. (Monroe to Madison, May, 1785.) That our entire country from the original thirteen states to the Pacific Ocean has been covered by what is no more or less than the New England township system is due wholly to their efforts. If this law had not been enacted and executed at the opportune time, the Virginia plan, with its attendant evils, would have prevailed. The ordinance was actually opposed long after its enactment. Madison in writing to Washington says: "Although the township plan of surveys had been adopted in May, 1785, the controversy between that system as the favorite of the Eastern people, and that of indiscriminate location, the Virginia plan, was still kept up. The states which had land of their own for sale were not hearty in bringing the federal lands into the market." (Madison to Washington, April 16, 1787.)

After Grayson's report had been considered one month, James Monroe, a Virginia delegate, wrote to Madison: "The original report admitted of the sale only of tracts containing thirty thousand acres called townships; this was adhered to with great obstinacy by the Eastern men and as firmly opposed by the Southern. At length, however, the Eastern people gave up this point, at least so far as to meet on middle ground. As it now stands it is to be surveyed into townships containing about twenty-six thousand acres each, each township marked on the plat into lots one mile square, and one half the county to be sold only in townships, and the other into lots." (Monroe to Madison, May, 1785.) That is, the New England members favored the township plan; the Southern members were in favor of indiscriminate location.

Grayson, who appears to have had charge of the bill, also wrote to Madison in about the same strain. "I shall give you

what I have in the manner the New England delegates wish to sell the continental land." "The matter is still under consideration, and other alterations will no doubt take effect." "An amendment is now before the House for making the townships six miles square." "Whether this will be carried out or not I cannot tell, the Eastern people being amazingly attached to their own custom to have everything regulated according to their own pleasure." (Grayson to Madison, May 1, 1785.)

It is interesting to know some of the arguments the New England members advanced in their zealous support of this ordinance. We have access to a few which Grayson gives in a letter to Washington. In fact, all we know of the inside history of this important piece of legislation is from several letters of Grayson's to different public men of that time.

1. "There certainly must be a difference in the value of the lands in the different parts of the country, and this difference cannot be ascertained without an actual survey at first."

2. "Because the Eastern states, where lands are more equally divided than in any other part of the continent, were generally settled in that manner."

3. "The idea of a township, with prospects of support for religion and education, would be an inducement for neighbors of the same religious sentiments to confederate for the purpose of settling together."

4. "The Southern method would defeat this end by introducing the idea of indiscriminate locations, which would have a tendency to destroy all these inducements to emigration."

5. "The exemption from controversy on account of boundaries for all time."

6. "The right to form governments for themselves would induce emigrants from all parts of the world and insure a settlement of the country in the most rapid manner."

7. "The expense and delay would be too great to divide the territory into fractional parts by actual survey."

8. "The method of laying out the same into squares is attended with the least possible expense, there being only two sides of a square to run in almost all cases."

9. "It supersedes the necessity of courts for the determination of disputes."

10. "It excludes all formalities of warrants, entries, locations, returns and caveats, as the first and last process is a deed."

What did the Virginia delegates have to offer against this array of argument? Nothing especially, except their antagonism to the New England township system. They claimed that the sale of the lands would be greatly delayed until they could be correctly measured, but their great cry was first, last and always, indiscriminate location. They insisted on the rule which would

give the most full scope to the roving emigrant, a policy which was carried out to the letter in the settlement of the Virginia Military Tract in Ohio, and in the states of Kentucky and Tennessee.

The Six-Mile Square Township.

The six-mile township comprised about the whole of the system of public land surveying when the law was first enacted. Principal meridians, base lines and standard parallels are improvements which were introduced later by different men connected with the surveys, and have since been sanctioned by law.

There has been a great amount of speculation about the origin of this township,—where it came from and why that particular size and who is responsible for its adoption in the ordinance of 1785. It has generally been considered an offhand creation, especially for the vacant lands of the Western territory, and proposed either by Capt. Thomas Hutchins or Gen. Rufus Putnam at the time the land ordinance was written. Like all other prevailing ideas and opinions about the origin of the rectangular system, this is not true, for it is a matter of history that the six-mile square township had its birth and grew to maturity in another part of the country generations before it was transplanted to the wilds of Ohio.

It is now known that Gen. Rufus Putnam was the first to suggest the six-mile township, which he did in a letter to Washington in 1783, in which he says that the tract of country between the Ohio River and Lake Erie, which is petitioned for, is large enough to contain seven hundred and fifty-six townships of "six miles square," and proposes to have it divided "by townships six miles square, or six by twelve, or six by eighteen, to be divided by the proprietors to six miles square, that being the standard on which they wish all calculations to be made." ("Life and Journal of Manasseh Cutler," Vol. 1, p. 167.)

But this idea was not original with General Putnam. He was only advocating a custom with which he had been familiar a long time. His letter to Washington might not have had a wide circulation, but that he exerted his great influence with the delegates from his own state is at least probable. He was a very prominent man, a practical surveyor and he appears to have been very much confirmed in his opinion how the Western lands should be subdivided. His prominence in the history of the early surveys and their origin is well established.

It is immaterial whether General Putnam was interested in

the land ordinance or not. The New England delegates did not require any outside influence, for they evidently had opinions of their own on the subject which must have been identical with Putnam's and derived from the same source. That they were familiar with the townships and town governments of their respective states goes without saying. That they were instrumental in reducing the seven-mile township to six miles is also certain. They were not satisfied with Jefferson's hundred, or Grayson's seven-mile tract, and as they were determined to have everything according to their own regulations, they insisted upon the New England method. Grayson, in his letter to Madison, says about as much, and it would be inferred from Monroe's letter of later date, though they were obliged to vote for other amendments which they did not favor. It was these men, and principally Rufus King, who, by way of argument, persuasion and compromise, inserted the six-mile township clause in the ordinance.

To find the real origin of the six-mile township we must go beyond Putnam's letter to Washington, beyond the ordinance of 1785; in fact, to colonial times, and we shall find that it is no more or less than a counterpart of those seats of local self-government that were planted in the New England colonies when first settled. (*Engineering News*, May 4, 1904.) All these states, with the exception of Maine, had been entirely covered with townships before the land ordinance became a law. They had become a firmly-established and vital principle whose great benefits and superiority could not be questioned even in other portions of the country where the system had not been adopted. During the formation of these townships, covering a period of at least one hundred and twenty-five years, they eventually developed into a uniform size if not a regular form, a tract of country about six miles square or its equivalent, which was considered to be the most suitable for the requirements of a well-appointed town.

In those parts of the New England states first occupied, the towns are of all sizes, shapes and directions, occasioned probably by topographical features of the country and local circumstances in settlement. They suggest a rude beginning, which they really were, before any well-defined plan had become necessary. Their boundaries were often broken and irregular, as if to inclose different groups of settlements or desirable pieces of land, or perhaps riparian benefits. Prof. John Fiske says that in the earliest settlements these tracts were generally anywhere from six to ten miles in either dimension, but some of them were much smaller.

As people moved westward a change for the better is noticeable, approaching more to regularity, as if the country was being uniformly settled. In the districts occupied latest, there is a marked improvement over all other portions of the country that is at once conspicuous. The towns approach nearer to a square or rectangular form, they resemble each other more in size and shape. They appear to have been laid out with a systematic attempt to make them neither too large nor too small, as if it had become the confirmed opinion that three miles or so was far enough for any resident to travel to his church or town meeting.

This is the result of a settled policy which had its origin in Massachusetts when people began to move westward from the first settlements on the coast. It was an effort to establish a standard size for the tracts of land that were being granted and occupied. This policy dates from 1634, when the General Court began making grants to individuals and communities for plantations which were settled as colonies by people from the older towns or by newly-arrived emigrants from England. The grants were generally made upon petition and after a legislative committee had viewed the land and reported. At a later date when the grants had become quite frequent, a permanent committee was appointed for this purpose. The boundaries were always surveyed and care taken to preserve the lines. The town outlines were generally controlled by local features and circumstances, but the size was always specified and never very large. The great requisite was desirable farming land, which often accounts for irregular forms. The Connecticut and Merrimac rivers also were controlling influences in many of the outlines, and the river was often a boundary. The formation and settlement of a plantation was always considered a matter of the utmost importance and was generally managed by the older town where the emigrants had lived.

"There were cases where tracts of eight miles square were granted, as at Groton, Mendon and Newbury. On the other hand, some of the older towns were quite small, but in general a tract six miles square or its equivalent was thought the best for a plantation." ("Johns Hopkins Studies," Vol. 4, p. 32.) Furthermore, it was a fixed policy to settle the unoccupied territory in a uniform manner and to grant a company of emigrants just what was required for agricultural interests and no more.

Perhaps the first mention on record of a piece of land for a town of this size was in 1652, when about twenty persons from Concord petitioned the General Court for a grant of land border-

ing on the Merrimac River, "to run by said river and to make up a quantity of six miles square." The grant was made of that size but in a rectangular form and incorporated as Chelmsford.

Probably the first grant ever made in a tract of this size with a square form was in 1656. Certain petitioners, inhabitants of Sudbury, asked for a grant to colonize. The General Court made the grant and specified six miles square. This was incorporated by the name Marlborough, and was probably the original regulation township. Another early instance was at Brookfield. The General Court made a grant in 1660 and specified six miles square. There was a similar one at Ashfield in 1690 and one at Northfield in 1672 where a grant was made of "six miles square in area, the length not to exceed eight miles." (Historical Collections of Massachusetts, Barber.)

This practice was continued as long as there was territory to give away, but as it was a rule with the General Court not to prejudice any plantation previously made, the six-mile grant was not always possible, but its equivalent in area was adhered to in a rectangular form. In fact, there are a large number of towns in Massachusetts which are not square, where the original grant distinctly called for a square. Here were people talking about tracts of land six miles square for settlement in a wild country and a legislature dividing its unoccupied territory into divisions of that particular size and form for town governments, over a century and a quarter before the ordinance of 1785 was enacted.

The following is an illustration of the New England plan for granting territory and forming towns. It gives the drift of ideas prevailing at that date. It was for a company of sixty neighbors who proposed to settle a new tract of country together.

"June 17, 1732, the General Court of Massachusetts granted six miles square for a township to be laid out in a regular form by a surveyor and chainmen, under oath. The said lands by them to be settled on the following conditions: That they, within the space of five years, settle and have on the spot sixty families (the settlers to be none but natives of New England), each settler to build a good and convenient dwelling house, of one story high, eighteen feet square at least, and clear and bring to, four acres fit for improvement, and three acres more well stocked with English grass; and also lay out three shares in the town (each share to be one sixty-third of the town), one share for the first settled minister, one for the ministry, and one for the school; and also build a convenient meeting house and settle a learned and orthodox minister within the time aforesaid." ("History of Hardwicke," p. 23.)

This was fifty-three years before the land ordinance, and the practice was continued still later. In the few years following grants of this size were very frequent, about twenty being made in three years, among which were four townships for building a wagon road, four for military services and one for the use of the Stockbridge Indians. Ten grants were also made in one body and sold at public auction in 1762.

Coming down to the latest date, we find that in 1781 the General Court of Massachusetts appointed a legislative committee to consider the disposal of all unappropriated lands in the Province of Maine, and in July, 1783, the county of York in that province was directed to be surveyed into townships six miles square. (JOURNAL OF ENGINEERING SOCIETIES, Vol. 3.)

These illustrations are taken from the earliest and the latest periods of town making, in a country where the work was brought to perfection. They are by no means all that could be enumerated, but they are sufficient to show where our standard townships come from.

At the time of the Revolutionary Was there were about two hundred towns in Massachusetts; probably fifty or more of them had been made equal to six miles square by grants or acts of incorporation. In Connecticut there were forty-six either six miles in both length and breadth or that amount in area. ("Historical Collections of Connecticut," Barber.) They are generally rectangular or trapezoidal in outline, although many approach closely to a square, with boundaries unusually straight and tending towards meridians and parallels.

It can be readily understood why public opinion concentrated on the six-mile size. It fulfilled in the best manner the purposes that a town was made for, which was a colony that must have its town meeting for self-government, its school and church. A four-mile neighborhood would be smaller than need be, one eight or ten miles in extent too large and inconvenient. The ideas of that early date in respect to the size of a town to suit its requirements are just as true to-day.

The townships planted in Massachusetts were only preliminary to what followed later in other parts of New England. The same system was extended to New Hampshire early in the eighteenth century by Massachusetts before the boundary line between the two colonies was established. Perhaps one of the first was at Londonderry about 1718, followed by others in the same vicinity. A continuous line of towns was also laid out from the Merrimac River to the Connecticut in 1726, all six miles square.

At the same time the province of New Hampshire was making grants on its own authority, and when Governor Wentworth came into office, he made it a special business to cover the country as rapidly as possible, and in 1761 he granted eighteen towns in one body bordering on the Connecticut River. Not all the towns in New Hampshire are of this size, a few are larger, and there are quite a number that would average only five miles in length and breadth, but the six-mile size was generally specified. In 1733 the town of Boscawen was granted and incorporated, a tract six and one-half miles long and six and a quarter wide, to ninety-one petitioners. From a very old history of the town of Bath the following is taken: "Like all other towns in this vicinity Bath was originally calculated to contain six miles square. Its length, however, exceeds its breadth by a quarter of a mile." (Massachusetts Historical Collections, Vol. 3, p. 105.)

In the north part of the state the towns are well laid off with regular boundaries and inclining very much to north and south and east and west directions. In the central part, which is a mountain and lake region, and also in the south, they are generally square but lie to all points of the compass. The six-mile square provision in these grants referred more to the size than the outline.

It was in Vermont that the regulation township reached its highest and most extensive development, for it was a fixed rule to adhere to that special size and form whether any rugged, natural features of the country interfered or not. In 1749 the first one was surveyed and granted at Bennington, by Governor Wentworth, of New Hampshire, to people of Portsmouth, for settlement. It will probably be interesting to land surveyors, especially in the West, to know that this was the first standard township ever surveyed in the United States with boundaries north and south and east and west.

With this township as a starting point he made grants very frequently during the following years, until 1764, when more than one half of the present state had been covered. Their number was one hundred and thirty-eight. All of them were made as nearly as practicable six miles square and were granted on the same conditions as the Massachusetts township. As a method of working in one part of the country, a line was measured along the Connecticut River in winter on the ice, for sixty miles, and a tree marked on each bank every six miles for corners from which the townships were laid off. In this manner three lines of towns

were surveyed on each side of the river, and sixty of them in Vermont were granted to colonists in one year.

When Vermont was made an independent state government in 1777, the legislature commenced at once to grant all unappropriated lands in the state, and at the time disposed of a number of townships. In 1780 charters were issued for about fifty more new townships, all on petition, and six miles square. All of these grants provided for the New England system of town governments, with sixty families to a town and sixty-five shares in each town, five of which were to be public rights, for the support of a college, for a county grammar school, for an English school, for the first settled minister and for the ministry. ("Vermont Settlers and New York Land Speculators," Benton.) In the north part of Vermont the towns lay diagonally towards the meridians, occasioned by working northwestward from the Connecticut River, but in the south, for about forty or fifty miles north of the south boundary, the townships were surveyed by meridians and parallels resembling very much the work in a western state. It was here, in fact, that the rectangular system was first put into practice. Gov. Benning Wentworth, of New Hampshire, anticipated the land ordinance of 1785 by thirty-five years. From 1749 to 1780, a period of thirty-one years, there were over two hundred townships planted in Vermont, every one of them six miles square. At the time the land ordinance was made a law there must have been at least four hundred in these northeastern states.

The New England delegates had grown up to these conditions and they carried their ideas with them to the Continental Congress. The legislation over the ordinance of 1785 was a conflict of opinions and embraced a wide scope, religious, political and sectional, but principally it was the town against the shire, and the New England plan prevailed.

Early Surveys and Methods.

One year after the enactment of the ordinance the first surveys were commenced in what is now Ohio, and for nineteen years they were confined entirely to that state.

The history of these surveys is generally well understood and there is no necessity of repeating it here. Ohio was a sort of experimental ground, divided into a large number of tracts, purchases, reserves, congressional lands and Indian territory, where many independent interests and various new and untried policies had to be exploited. As a result, before the surveys had

proceeded very far, it was found that they were being loosely and irregularly executed, and for good reasons. The country was rough, wild and difficult to operate in. There was always great danger from hostile Indians. The system, crude at first, had not received its finishing improvements. It was not until an entirely new territory was ready to be opened up that Surveyor-General Mansfield was able to introduce any refinement of method and regularity into the work. This was done in what is now Indiana.

While the ordinance was under consideration, and during the survey of the different tracts in Ohio, there were a number of methods proposed and used for subdividing townships and numbering the sections.

Grayson's report did not explicitly state how the forty-nine sections should be marked on the township plat, and the law as finally adopted contained the same omission. A section of the final ordinance reads: " The lots shall be numbered from one to thirty-six, always beginning the succeeding range of the lots with the number next to that with which the preceding one concluded." This would admit of sixteen different methods of numbering a township. It is probable that this part of the work was intended to be left to the judgment of the geographer. At any rate, Hutchins pursued a plan of his own and in the first townships surveyed in the Seven Ranges he commenced with number one at the southeast corner and numbered north through each range of lots to number thirty-six in the northwest corner.

He appears also to have had ideas of his own about marking the lines, for instead of following the incomplete method of the law, which was merely chops on trees, he set a post at every mile and marked a witness tree on each side. The act of May 18, 1796, changed Hutchins' numbering to the present method.

During the first four years of surveys in the Military Bounty Tract, townships were made five miles square, divided into quarters and numbered from one to four. After this, fifty of those quarters which had not been sold were divided into lots of one hundred acres each. All the remaining lands in the tract were subdivided into " sections."

The Western Reserve was surveyed under direction of Surveyor Seth Pease, from 1796 to 1806. The work was very much superior to the congressional surveys made at the same time. The range lines were called principal meridians and were all run due north. Townships were five miles square and divided into quarter towns of 4 000 acres each.

While in office, Surveyor-General Mansfield was asked for

his opinion about the expediency of dividing all sections into quarters at the time the section lines were run. He reported unfavorably, principally on account of the additional expense, but said that in the Indiana surveys all quarter corners had been built on section lines when they were surveyed.

The law of May 18, 1796, introduced an improvement in the work of running section and township lines. It provided among other things for the marking on trees, one in each section, near to the corner, the number of the section town and range. The law of May 10, 1800, originated the present method of running the section lines north and east, and for throwing the excess or deficiency, as the case may be, on the north and west lines of quarter sections. Some practical surveyor must have been responsible for this innovation. It is the opinion of those who have been engaged on public land surveys that it would be a great improvement in subdividing a township to divide it into quarters at first, and then complete each quarter by the above method.

Waynes' treaty line was an important and controlling function in the Ohio surveys. It separated the Congress lands from Indian territory and limited the extent of the surveys on the West until 1805. It was surveyed in 1798 by Israel Ludlow.

In the country south of the Military Tract and west of the Ohio Purchase the surveys became very much distorted, and to correct them a new meridian was run from the Ohio River northward between ranges 17 and 18. All the irregular work on the east was closed up to this line, and new and correct surveys commenced on the west, which were continued to the Scioto River. In some cases a quarter section on the east was as large as a whole section on the west. This line was not strictly a true meridian, but was intended to be parallel to all other range lines in that part of the country. Its correct direction is about four and one-half degrees east of north.

The survey of the country between the Great and Little Miami rivers, or what was intended at first to be Symmes Purchase, was a curious proceeding, but it is interesting because it was here that a meridian and base line were run and called by those names, although ranges and townships were not numbered from them.

From the most southerly point of land on the Ohio River between the two Miami rivers, a line was run due north, by Israel Ludlow, to the Great Miami, a distance of about twenty miles, marked with corners at every mile and called a first meridian.

At six miles a line was run east to the Little Miami and one west to the Great Miami, marked with corners at intervals of a mile and called a base line. From these corners one mile apart, lines were run north by magnetic needle, fifteen miles from the base line. The east and west lines were not run. A line was then run north six miles without any marking, across range number three. Then an east and west line between the two Miami rivers marked every mile and called a second base, which was the south boundary of the fourth range. Then lines north from this second base to the north line of the sixth range; then another east and west line from one river to the other." ("History of Butler County, Ohio," p. 24.)

In this manner the surveys were continued for some distance northward. This was in 1788 and 1789. Afterwards most of these lands reverted back to the federal government and were resurveyed under General Putnam's direction during 1802 and before by somewhat the same method. The townships present a strange appearance on the map. Ranges are numbered northward from the Ohio River, and towns east from the Great Miami, a system directly opposite to that of the others in Ohio.

The survey of the country between the Great Miami River and the Greenville treaty line was a mismanaged work, yet there was one great improvement made over what had been done before which must have influenced Mansfield in the Indiana system. As a first step the Indian boundary on the west was run in 1798, and in the fall of the same year, a line due north from the mouth of the Great Miami River to the same treaty line near Fort Recovery, a distance of about ninety miles. Both of these lines were surveyed by Israel Ludlow, who was the ablest and most prominent of the Ohio surveyors. The last line was expressly for a principal meridian and was used to number ranges from east and west. This was two years before Indiana was made a territory, and four years before Ohio was admitted as a state, but it had been known since the ordinance of 1787 that such a line would be the eastern boundary of the second state formed out of the Northwest Territory. This was called the First Principal Meridian, after Mansfield had established the second in Indiana. This line was extended north of Fort Recovery in 1817 as a state boundary.

In the south part of this tract, near the Ohio River, the surveyors ran the township lines east and west, then the range lines south, and subdivided the country. North of this they ran the range lines in the eastern part of the tract at first, and later towards the west, closing on the principal meridian, contrary to

a well-conducted survey. Townships were numbered north from the Ohio and Miami rivers, making a number in a range on the east in some cases six and twelve miles north of the like number in a range on the west. Of course, General Putnam had his reasons for working in this manner, nevertheless, it will always appear strange that he did not have the originality to establish a base line for this tract.

There was one provision in the ordinance of 1785 that Surveyor-General Putnam did not like. The north and south lines were to be run by the true meridian, but it appears that he disregarded the rule in the surveys made under his direction. On March 10, 1798, he directed a letter to Congress in which he asked for the repeal of that part of the law and gave several reasons why it was necessary.

"It would be exceedingly inconvenient and embarrassing, if not altogether impracticable, for the deputy surveyor to run lines in that manner.

"There is a difference in the variation of the magnetic needle at different places and at no great distance from each other in the Northwest Territory so that a compass rectified or adjusted to the true meridian in one place will not cut that meridian in all parts of the country or in the tract to be surveyed.

"It would take very frequent observations to discover whether lines are being run according to the true meridian or not.

"In the surveys of the lands west of the Seven Ranges to the Scioto River, and in the Military Tract, the north and south lines were run as nearly as possible parallel to the west boundary line of the Seven Ranges, and all the compasses of the surveyors were rectified to one meridian corresponding to that boundary line.

"He had instructed two of his surveyors, on whose ability he could depend, to ascertain the variation of the needle from the true meridian in various parts of their districts, but they both failed in the attempt by reason of fogs, clouds, etc.

"An attempt to survey by the true meridian will be impossible to carry through in an uniform manner, and the lines would not correspond so well with each other as if surveyed by the meridian adopted for the Military Tract."

This letter was referred to a committee who reported that it would be improper to repeal that part of the law mentioned. General Putnam was afterwards removed from office on account of poorly executed surveys, and this indiscreet letter might have had something to do with it. His great fault was that he made no effort to run lines by the true meridian, and follow the requirements of the law. (Public Lands, Vol. 1, p. 73.)

MANSFIELD'S RECORD AS SURVEYOR-GENERAL.

Jared Mansfield was the first person ever appointed to an office under the government on account of his scientific attainments. His arrival at Marietta in the fall of 1803 was none too early, for during the few years previous the public surveys had been going from bad to worse, and it was time for some effort at correction. There had been too little regard for a true meridian, too much inattention to magnetic variation, and perhaps considerable general carelessness. As a result, the surveys had become greatly distorted, and if they had been continued in that manner, the rectangular system would have been doomed to an early failure. That an effort was finally made to improve the work is entirely to the credit of President Jefferson.

Mansfield had little to do with public surveys in Ohio. General Putnam, while in office, had pushed the work energetically, and at the end of 1803 about all the country south and east of Wayne's Treaty line had been surveyed at least into townships. Mansfield's work was confined principally to the country between the Western Reserve and the Military Tract and in subdividing townships in different parts of the state.

In 1805 he moved his office to Cincinnati and in the same summer he went to Indiana to establish the Second Principal Meridian. The Vincennes Tract, so-called, had been surveyed the year before under his direction. This was a piece of land about forty miles wide by seventy-five in length, ceded by the Indians in 1803, the only settled portion of the territory. The base line was first run its whole length, about one hundred miles, passing nearly midway through the country to be subdivided. From this initial line ranges and townships were laid off, north and south, so that by the end of 1804 nearly the whole tract had been subdivided.

The next year, the Second Principal Meridian was laid out, at first a short distance north, then south about thirty miles to the Ohio River. In that season and during the next seven years surveys were extended in all directions until the ceded lands had been covered. The subdivisions immediately followed the Indian cessions, which were five in number.

Mansfield's work was necessarily confined to the southern part of the territory. The whole central part was Indian land until 1818 and the northern part still later. In 1819 surveys were immediately extended northward and the country opened to settlement. This is why the base line was placed so far to the

south. It was the Vincennes Tract that governed the location of both Principal Meridian and base line.

At the end of Mansfield's term of office in 1812, the Second Principal Meridian had been laid out about fifty miles north of the base line. That part of Indiana below or south of the townships numbered ten north had been covered with surveys and to some extent northwest of this in the vicinity of Terre Haute, also a narrow tract, twelve miles wide, on the east and immediately west of the Greenville Treaty line, extending half way up the western border to Fort Recovery, known as the Harrison Purchase, and ceded in 1809. This was all that could be done up to that date, and comprised about the south third of the territory.

The Indiana base line was extended west through Illinois to the Mississippi River, and the Third Principal Meridian south to the mouth of the Ohio, opening up the Illinois system of surveys. All the country south of the base line was subdivided in 1813 and 1814 and the lands put on the market. The Third Principal Meridian was not extended north of the base line until 1815.

There is nothing on record to show that Mansfield planned the Fourth Meridian, which was surveyed in 1816, but he probably did. E. D. Mansfield says in his "Personal Memoirs" that his father established three principal meridians in Ohio and Indiana while Surveyor-General, but as he had nothing to do with the First Meridian, this must mean the Second, Third and Fourth in Indiana and Illinois.

The rectangular system of surveying when first enacted into a law was not complete. It was a structure well enough so far as it had been built, but it had no supporting framework. What should have been supplied at first was created last, and this was Mansfield's achievement.

It is true there had been principal meridians and base lines in the Western Reserve, the Military Tract and the Fourth System of surveys before the Indiana work was commenced, but they were boundary lines, used by the surveyors for numbering ranges and townships. It had not occurred to any one connected with the earliest surveys to establish lines for that special purpose.

In the country beyond Ohio, Mansfield found a vast tract inclosed by the Ohio and Mississippi rivers and the Great Lakes that some day would be covered with townships. There must be a base line of some kind which surveys could be commenced from and referred to. He conceived the idea of two astronomical lines, a meridian and a parallel of latitude, independent of any

state boundaries that might be subsequently established, from which the townships could be laid off in four different quarters, and not necessarily to a great distance. He simply established a primary control where none previously existed. When surveys had been extended sufficiently far from one base and liability to errors incurred, another could be established for a new system of work. The four quadrants were different fields where surveys could be conducted independently of each other and errors in execution reduced to the least possible.

This conception was, in fact, the rectangular system of coōrdinates put to a practical application on the western prairies and very probably derived from Descartes geometrical invention of 1628. The base line and meridian are the two axes, and the range and township members, the ordinates. A point in any quadrant is definitely fixed.

This was Mansfield's part in the formation of the rectangular system, a base or framework for an extensive system of townships covering a large tract of country, which would insure uniformity and regularity in the execution of the work, a plan so obviously excellent that it has been continued over the whole public domain. It is the extensive use that was subsequently made of Mansfield's improvement that raises it to importance which it otherwise would not have had.

The rectangular system, like all other great inventions, was more of a process of evolution than a first-hand creation, for which no one man is responsible. Mansfield has always occupied the most prominent position in the history of the early surveys, and no one would wish to detract from his reputation. Without his interior meridians and base lines the system would have been forever cumbersome and difficult to execute. In fact, it could never have been extended over an extensive country as it had been conducted in Ohio. He was the first to plan and superintend a correct system of surveys which has been a prototype for all those that followed. On this alone, his reputation will always rest.

Nevertheless, it is evident when the actual historical facts are known that Mansfield's work in the development of the rectangular system has been overrated. Creditable as it was, it does not deserve the praise that has been attached to it when the work done before his time is considered. There is no great or original conception in the idea of the Indiana principal meridian with its base line. If General Putnam had been an educated and scientific surveyor, which he was not, he would have anticipated

Mansfield by establishing a base line for the fourth system of surveys instead of numbering townships from the Ohio River. Fortunately or unfortunately, Mansfield has received a considerable amount of advertising, for what very little there is on record about him and his work is entirely of that character, both misleading and incorrect.

Edward Tiffin's Record.

The rectangular system was not complete when Mansfield resigned his office in 1812 and it remained for Edward Tiffin, his successor, to supply the deficiency. So far during the progress of the surveys nothing had been done about the convergence of meridians. A tract of country was considered a plane surface, and the surveyors were attempting to divide it into squares with spherical lines as boundaries, an impossibility that had attracted attention at the earliest date. When the land ordinance was first reported in Congress in 1785, Timothy Pickering wrote at length to Rufus King, the Massachusetts delegate, and called his attention to this feature in the proposed method of surveying the government lands.

"The first paragraph orders the manner of dividing each new state into hundreds, but it seems to me it will be found impracticable. Each hundred is to be ten miles square, yet the lines making the eastern and western boundaries are to be true meridian lines, but meridian lines converge as you increase the latitude, and to such a degree that if you take any meridian, say at the thirty-ninth degree of latitude, and on that parallel set off ten geographical miles from such meridian, and then proceed northward to the forty-first degree of latitude, and then from the same meridian set off the like number of ten geographical miles, their extremity will be about eighteen hundred feet beyond the meridian, of the like extremity at the parallel of thirty-nine degrees. I am aware that mathematical accuracy in actual surveys may not be expected, but a difference of six hundred yards in ten miles would surely produce material errors." ("Life and Letters of Rufus King," Vol. 1.)

Congress paid no attention to this suggestion, and probably General Putnam never gave it a thought during the progress of the Ohio surveys. It would be doing Mansfield an injustice to say that he ignored it or intended to in his plan of improvements. But if he did propose or contemplate some method to obviate the difficulty, there is nothing on record to show it. That he did not establish a standard parallel from the Second Principal Meridian at thirty-six or forty-two or forty-eight miles north of the base line must have been because, in his opinion, the surveys had not

been extended far enough. However this may be, there is nothing to do but take the surveys themselves for a record and give Edward Tiffin the credit for providing a method to rectify this meridional convergence.

When the Indiana surveys were being extended northward after the Indian treaty of 1818 it would appear at first that he either ignored the convergence or was undecided when it had grown large enough to require correction. In 1819 the first standard parallel was run from the Second Principal Meridian ninety-six miles north of the base line, a distance too great, but the mistake was not repeated. The convergence of two range lines in this case would be about one eighth of a mile, or 640 ft., making a deficiency on the west side of townships altogether too large. He must have recognized this error, for in the same year he gave directions to all deputy surveyors about establishing a "new base or parallel to the equator" every twenty-four or thirty miles, lines which were known later as Standard Parallels or correction lines. (Niles Register, Vol. 16, p. 362.)

All of Illinois south of the base line was subdivided in 1813 and 1814, but a standard parallel was not considered necessary for the work, possibly because the tract of country was too small. After 1819, when William Rector was surveyor-general of Illinois, Missouri and Arkansas, one was surveyed on the west side of the Third Principal Meridian thirty-six miles north of the base line, another at fifty-four miles and a third one at thirty miles. On the east side they were placed at forty-eight, forty-two and thirty miles. At this date the Illinois system was far superior to any other work that had been done.

Edward Tiffin was surveyor-general ten years and made an excellent officer. Under his direction the Fifth Principal Meridian, the Michigan Meridian, was established, and perhaps the Fourth. He also adopted the west boundary of Ohio north of Fort Recovery as a continuation of the First Meridian and ran a base line for it on the forty-first parallel. He directed the surveys in central Indiana, in all the southern part of Illinois, to some extent in Arkansas and Missouri territories and all the northwestern part of Ohio, completing that state.

He made other valuable improvements towards systematizing surveys and methods and the sale of lands. He was the first to draw up an elaborate series of instructions for deputy surveyors in the conduct of their work, which governed all surveys for many years. These instructions were very complete and covered every detail of the work, prescribing one uniform method

which all were required to follow, and making a necessary interpretation to the land laws on the statute books at that time.

It would be quite correct to say that at the end of Edward Tiffin's service, the rectangular system of surveys was complete.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by February 1, 1909, for publication in a subsequent number of the JOURNAL.]

SOME OBSERVATIONS OF METHODS, COST AND RESULTS OF SEWAGE PURIFICATION ABROAD.

By H. W. Clark, Member of the Boston Society of Civil Engineers.

[Read before the Sanitary Section, October 7, 1908.]

To one familiar with sewage purification in America, there are a number of points in regard to sewage purification abroad that are impressed upon his mind more strongly by a short visit and inspection of English and other works than by much reading of engineering literature and Royal Commission or other reports.

In the first place, the number and proximity of sewage purification plants, especially in England, is forced upon one's attention at every hand; second, the variety of methods followed, and the variety often followed by one municipality, it being no unusual thing to find at one plant sewage farming, chemical precipitation, septic tanks, contact filters, trickling filters and secondary filters; third, the different methods of operating similar plants at different places; fourth, the curious lack of knowledge that often obtains at one borough in England in regard to methods and results at a neighboring borough in spite of associations of sewage works managers, etc.; fifth, the solidity and cost of works that are in a sense, even although the works of a large community, only experimental as yet; sixth, the fact that sludge disposal is still the chief problem in spite of all the work upon septic tanks and other methods of destruction; and, finally, the great part that chemical precipitation still plays at both old and new sewage plants, principally, however, as a preliminary treatment, although there are many huge precipitation plants without further methods of purification.

One has only to look over the curious mixture of works and methods to realize that in spite of vast expenditures, sewage purification in England is still in an experimental stage and that much money has been expended unwisely, in some cases, in endeavoring to meet the requirements of Rivers authorities and other official bodies without sufficient time for study and experiment, and in other cases simply from wrong construction. The report of the Royal Commission on Sewage Disposal just issued is, however, a comprehensive document, full of

valuable data and conclusions, and cannot fail to be of great aid in guiding the method of construction of plants yet to be built. This question of sewage disposal is a very serious one with our English friends, and they are taking it seriously and expending vast sums of money on every hand. In Germany, modern methods are not so much to the fore as yet, although good experimental work is being carried on and some elaborate screening plants are being erected. The Germans are watching English work, imitating it in some places, but are going slowly enough to avoid many costly mistakes.

During May, June and July of the present year I visited a large number of English and German plants and had an opportunity to talk with many of the prominent experts on this subject. To-night I propose to discuss the kind of sewage plants that are being built and operated in England and elsewhere abroad: how they are being built, why, and based upon what results; what some of them are costing, and, finally, to discuss the results.

Sewage Farming.

Sewage farming is still in successful practice in England at many places, and many of the modern works are part and parcel of the old sewage farms, built upon them and run in conjunction with them. Birmingham, for instance, where there is, as you know, one of the most notable displays of septic tanks and sprinkling filters in England, has besides this modern plant the old 3 000-acre sewage farm. This farm is being put out of use, however, and when the filters now under construction are finished, it will probably be entirely rented to farmers.

Of a number of farms that I visited, that at Wolverhampton, a city of 102 000 people, is representative, I believe, of good management under average conditions. The ordinary flow of sewage at Wolverhampton is 3 000 000 gallons daily and several times that during storms. All this sewage is cared for, however, which cannot be said of every English sewage farm. The sewage is first treated with lime and then passed through settling tanks to land. The farm is 600 acres in area, and of this area, 450 acres are used for sewage disposal. The sludge from chemical precipitation is pressed into cakes and burned or used to fill in lowlands over the farm. The sewage passes in shallow channels and the farm is drained with tile pipe 3 ft. 9 in. deep and with the lines of underdrains about 30 ft. apart. At times of excessive storm the storm-water flows into a storm

reservoir, eleven acres in area, with earth embankments 3 ft. high. Here it slowly filters away through the gravelly bottom. The effluent of this farm feeds a trout brook and, in fact, is perhaps the main source of this brook. It is, of course, good in quality and equal to that of the best Massachusetts sand filter plant. The total expenditure upon this sewage works and farm up to the end of March of the present year was $750 000, or about $7.50 per head of population. The cost of operation for the year ending March 31, 1908, less the profit from the farm, was $26 000. Including interest and sinking fund the yearly cost was slightly more than twice this, — about $56 000. The average rate of filtration on the farm is about 8 000 gal. per acre daily, the working cost $22 per million gallons and the cost per million gallons, including interest and sinking fund, $49. The cost of purification per million gallons at the eight farms reported upon by the Royal Commission in its recently issued report varies from a little less than $6 to about $77. I believe, however, that Wolverhampton is a typical farm, neither as large as that at Nottingham nor as small as some of the farms reported by this commission. In regard to sewage farming, the Commission states in its conclusions that where land can be bought for not over $500 per acre, land treatment is probably, other things being equal, the cheapest method of purification. With suitable land, it certainly gives the best results. From a cursory observation of English sewage farms I am led to believe that much of their ill repute is due to the use of land fairly well adapted to farming but poorly adapted to sewage purification.

AVERAGE ANALYSIS OF WOLVERHAMPTON RAW SEWAGE AND TANK EFFLUENT.*

(Parts per 100 000.)

	Ammoniacal Nitrogen.	Albuminoid Nitrogen.	Oxygen Absorbed in 4 Hours at 80° Fahr.	Combined Chlorine.
Raw sewage........	4.50	0.91	6.53	19.9
Tank effluent.......	4.79	0.45	4.64	19.0

AVERAGE ANALYSIS OF "OLD" AND "NEW" LAND EFFLUENTS.*

(Parts per 100 000.)

	Ammoniacal Nitrogen.	Albuminoid Nitrogen	Nitric Nitrogen.	Oxygen Absorbed in 4 Hours at 80° Fahr.	Combined Chlorine.
Old land........	0.63	0.044	1.24	0.56	15.4
New land.......	0.68	0.042	1.11	0.52	15.0

* For year ended March, 1907.

Contact Filters.

As you well know, contact filters began to be talked about very earnestly about ten years ago and much was claimed for them. At the present time, while large contact filters are in operation at many places in England, notably at Manchester, and similar filters are being constructed on a large scale, notably at Sheffield, the general tendency is towards the construction of percolating or sprinkling filters. The forty-six acres of Manchester contact filters are of heavy concrete construction and the filtering material is coke or clinker. At the present time, owing to the better results known to be given by percolating filters, the Manchester authorities are experimenting upon changing the method of operation of these contact filters. That is to say, certain filters are being operated with unchecked outlets and with sewage flushed over the surface every fifteen minutes, the sewage rising in concrete chambers placed in the filters and spreading by means of surface channels. The new secondary filters under construction, in order that double filtration of the sewage may be possible, are being built to try to meet the requirements as to effluent of the Mersey and Irwell Joint Commission. They will be thirty acres in area. These filters are of heavy concrete construction, and while the first intention was to use coke or clinker as the filtering medium, it is probable that some at least will be of broken stone. The total cost of the Manchester works to date has been about $2 500 000 although a considerable portion of this has been for parts of the works not at present used, and the new beds, tanks and conduits will add $400 000. Thirty-five million gallons of sewage come to the Manchester plant daily with the average dry weather flow. No chemicals are used, but the sewage passes through large fat separators, so called, and septic tanks before going to the filters. At the present time all the contact filters are being cleaned; that is, all the clinker and coke in these filters is being removed, washed and replaced. This removal, washing and replacing costs about 15 cents per ton, and three hundred and fifty tons were being removed, cleaned and replaced daily at the time of my visit. As nearly as I can estimate from the Manchester reports, the working cost of this plant is 15 cents per person per year, or about $9 per million gallons of sewage filtered. One hundred and fifty men are employed. However, the effluent of this filter plant is pronounced unsatisfactory; in fact, "bad" by the Mersey and Irwell Joint Commission, and constant reminders are being sent to the Manchester authorities that its

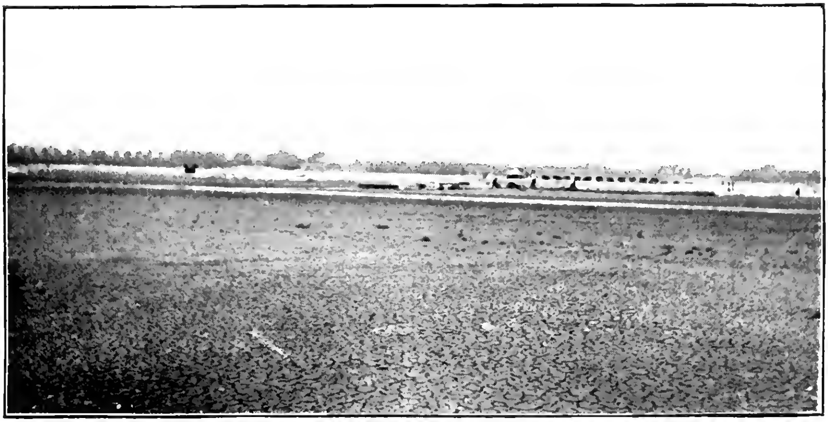


FIG. 1. MANCHESTER CONTACT FILTERS.

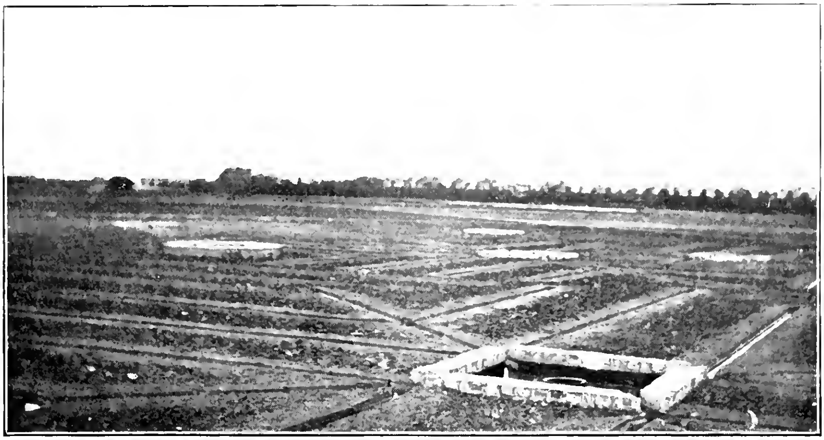


FIG. 2. CONTACT FILTERS AT MANCHESTER CHANGED TO PERCOLATING FILTERS.

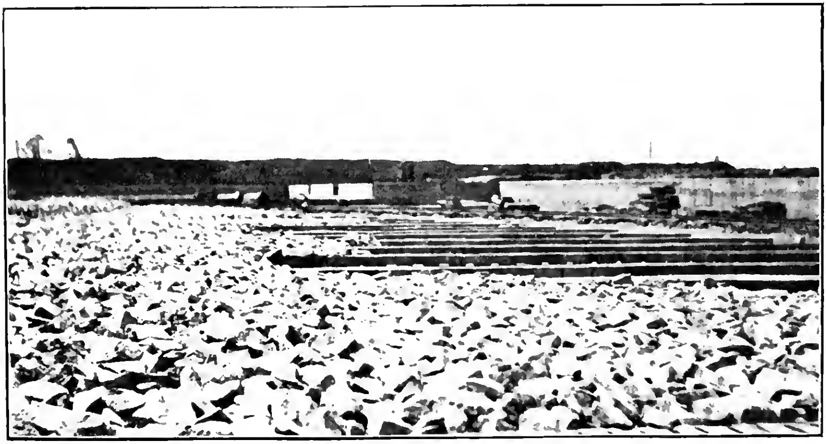


FIG. 3. BUILDING SECONDARY CONTACT FILTERS AT MANCHESTER.

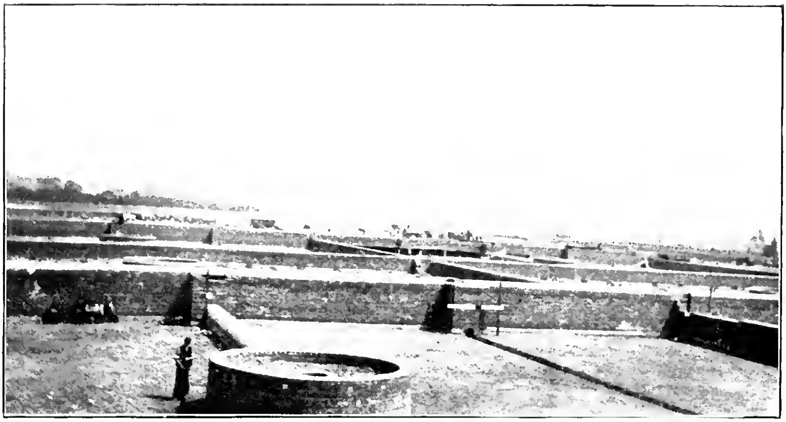


Fig. 4. Constructing Contact Filters at Sheffield.

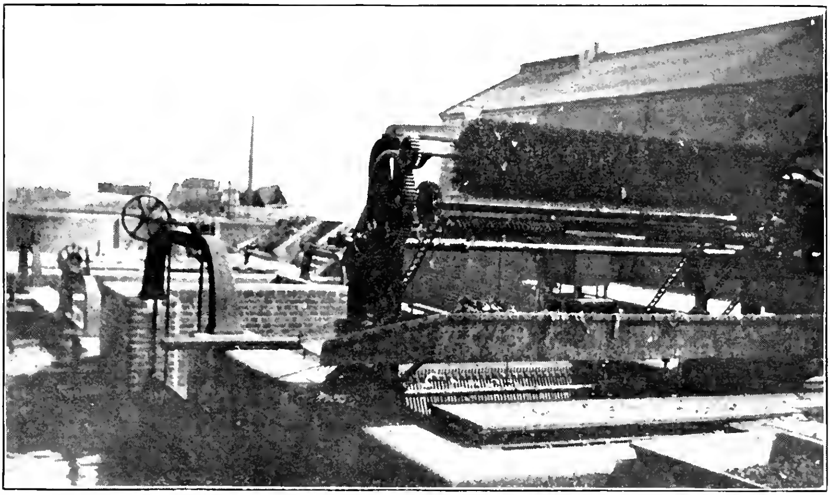


Fig. 5. A Typical English Screening Plant.

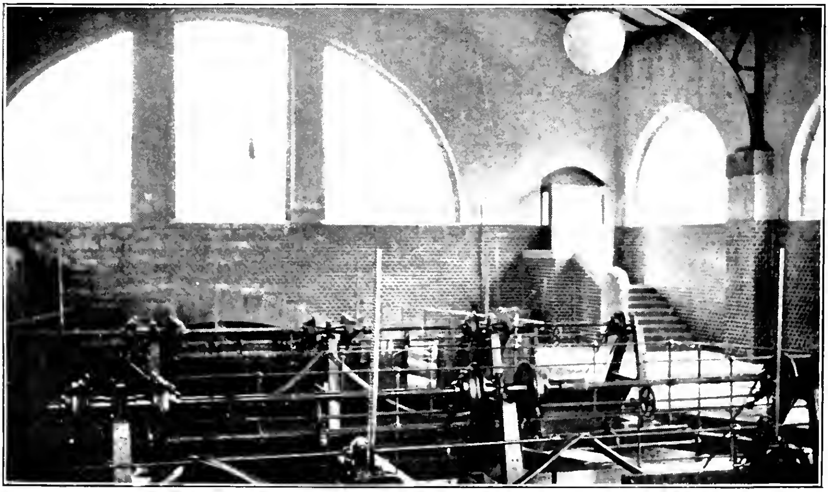


Fig. 6. A Typical German Screening Plant.

quality must be improved. Owing to these reminders the secondary filters are now being constructed, but it is a serious question whether even with this addition to the plant the effluent will fulfill the requirements of the Rivers Commission. The effluent is often putrescible, according to Dr. Scudder, the chemist of the commission, and the purification not what it should be even though only a non-putrefactive effluent is the highest standard sought. No chemicals are used at Manchester, and Dr. Fowler, in talking with me in regard to the removal and cleaning of the material of all these filter beds, stated that in his opinion the retention of solid matter in them, even though this necessitated complete removal and washing of material every few years, was much cheaper than the use of chemicals to remove matters in suspension before filtration. This may be true, but the evidence of other contact filters in England is that much better effluents are obtained when chemical precipitation precedes filtration by such filters. I consider Dr. Fowler to have, perhaps, the greatest information in regard to sewage purification of any English expert, but I believe that the problem of making the Manchester filters do work satisfactory to the Mersey and Irwell Commission almost hopeless unless percolating methods can be adopted.

Notwithstanding the general disfavor in which contact filtration is held at the present time in England and the failure of the Manchester sewage works, according to the chemist of the Mersey and Irwell Joint Commission, such a community as Sheffield, having a population of 450 000 people and with an average daily flow of 15 0000 00 gal., is constructing contact filter beds. At Sheffield, since 1886, the main purification has been chemical treatment with lime and large settling tanks. In the new scheme, 16 settling tanks are being constructed, each with a capacity of 1 000 000 gal., and chemical treatment is to be omitted. The authorities at Sheffield state, however, that it is not intended to depend upon septic action in these tanks as a part of the scheme of purification. Thirty acres of contact beds in half-acre sections and sixteen acres of similar storm-water beds in acre sections are being constructed. All these contact beds are most solidly built with brick walls, concrete bottoms 6 in. thick and brick and concrete channels. The beds are to contain 4 ft. in depth of clinker over the underdrains, and the main underdrains are being built of concrete below the floor of the filter with tile coverings, and side drains 10 ft. apart entering these are laid on the concrete flooring.

The material of the bed is to be of graded clinker 3 to 6 in. in diameter at the bottom and becoming finer towards the top, the upper six inches to be constructed of clinker not more than $\frac{1}{4}$ or $\frac{3}{8}$ in. in diameter. The sewage is to pass to these contact beds through a channel built between each set and will enter the bed through a 2-ft. pipe to a chamber in the center of the bed where it will rise and overflow to a second circular chamber 15 ft. in diameter. From this it will pass over the surface of the beds in channels formed of the fine surface coke. The building of contact filters at Sheffield is a result of the operation for ten years, of large experimental contact filters treating 1 000 000 gal. of sewage daily. These filters produced an effluent equal to the requirements of the Local Government Board, and it is stated that the filtering material was never cleaned or renewed during their period of operation. The new filters are being built upon hard pan and clay, but notwithstanding this, the Local Government Board is insisting upon concrete bottoms 6 in. in thickness, causing a large expense that apparently is needless. The cost of the new plant complete is estimated at $1 500 000, or practically $60 000 per million gallons of daily capacity. The Royal Commission estimate the cost of a plant for contact filtration to vary from $42 000 to $134 000 per million gallons of daily flow, the cost varying with the preliminary treatment.

At Rochdale I saw five acres of contact filters that cost $6 000 per acre. These filters are simply excavations without concrete bottoms, and with earth instead of concrete dividing walls. The effluent was not particularly good on the day of my visit. At Blackburn there are four acres of contact filters, two primary and two secondary, and these filters receive about 1 200 000 gal. per day, or 300 000 gal. per acre. They are $4\frac{1}{2}$ ft. deep, of concrete construction and divided into many small areas; the filtering material is coke and clinker mixed, none of which is over $1\frac{1}{2}$ in. in diameter, and the sewage is treated with chemicals and passed through large settling tanks before filtration. Over the surface of the primary contact beds tile pipe is laid with close joints, and on the top of this tile pipe are fine slits about $\frac{1}{8}$ in. wide and 1 in. long, these slits being 4 or 5 in. apart. The sewage entering under the head given by its level in the sedimentation and septic tanks is projected upward from 3 to 5 ft. and sprays to a considerable extent, especially when the wind is blowing. From the primary beds the sewage passes to the secondary beds and is distributed by wide troughs laid closely over the surface of these beds. The troughs are about

6 in. deep and have $\frac{1}{2}$ in. holes near the top through which the sewage flows. On the day of my visit the effluent from the secondary filters was clear and odorless and contained about 0.06 of a part of albuminoid ammonia and fairly good nitrates. That is to say, at Blackburn, largely by use of chemicals and the removal of most of the suspended matter, and by double filtration through contact beds of fine material, a satisfactory effluent is obtained. These four acres of contact beds cost $100 000.

Sprinkling Filters.

I saw in England and Germany representative percolating or sprinkling filter plants. Such plants as those at Salford, Heywood, Horwich, Blackburn, Accrington, Chesterfield, Buxton, Hanley and Birmingham illustrate most, if not all, types of construction and operation, and produce a variety of results.

I shall talk briefly to-night about six or seven only; namely, the plants of Heywood, Blackburn, Chesterfield, Hanley, and Birmingham. These are typical plants of representative cities. The Heywood plant I was told by the Mersey and Irwell River authorities was giving one of the best effluents in the neighborhood of Manchester. Heywood is a city of 27 000 people, about eighteen miles from Manchester, and has an average daily flow of 1 100 000 gal. of sewage. The sewage is first screened, then treated with chemicals, passed through settling and septic tanks and then to sprinkling filters. A small portion of the sewage, however, passes to contact and sand filters that have been in use for quite a number of years. The chemical used is alumino-ferric, and the amount about 4 grains to the gallon. Mr. Bolton, manager of the works, stated, in distinction from the statement of Dr. Fowler, that the use of chemicals was in his opinion cheaper than removing, cleaning and washing filter material. The screens used are typical of those in use all over England, with automatic rake and brush cleaners moved by power. The power employed at many places about this plant is generated at a garbage disposal plant on a hill just above the sewage works. An automatic apparatus is in place to change the flow of sewage from one bed to another. It is a most complicated and ingenious affair, but I understand works fairly well. There are six or seven men employed all the time, however, within a stone's throw of the little house in which this apparatus is lodged, and possibly manipulation by hand

would be fully as sure and effective. Automatic apparatus is common in England at many of the sewage works, but in many places it is evident that it causes much trouble. The sprinkling filters at Heywood are 12 in number, 60 ft. in diameter, or about $\frac{1}{15}$ of an acre in area, and 8 ft. in depth. They have brick pigeon-hole walls, 15 in. thick at the bottom and 9 in. at the top, heavy concrete bases, and the sides are buttressed, owing to springing of these sides after they were built and filled with clinker. They are filled with pieces of clinker each with a diameter of 5 to 6 in., and each filter generally operates an hour and then has an hour of rest. The sewage is distributed by the revolving type of distributor, the so-called "simplex" distributor being in use here. The usual rate of filtration is 1 400 000 gal. per acre per day. The effluent of the filters passes through a settling basin holding about four hours' flow, then over baffles into the river Roche. On the day of my visit the final effluent was very handsome, well nitrified, and practically all the matters in suspension were being removed by the final settling tanks. The effluent made a clear streak in the river Roche into which it flowed; that is, it was of a much better appearance than the river water, although I was told by Mr. Bolton that the river had been improved very much of late years. Each filter cost, complete, with sprinkling apparatus, $2 900, or $34 800 for the set of 12 beds or $43 500 per acre of filter surface. Of course this is only a portion of the cost of the plant; the total cost for chemical precipitation plant, screens, settling tanks, etc., was $325 000. The working cost per million gallons of sewage treated is $10.50, practically the same as for chemical treatment alone at Worcester, Mass.

Blackburn is a city of 100 000 people and resembles somewhat in size and character the city of Lowell in this state. The average daily flow of sewage at Blackburn is 5 000 000 gal., although this doubles and triples at times of storm. A sewage farm has been in use for many years, consisting of 500 acres of land, largely clay land, let out to farmers. This farm is being abandoned and very elaborate and expensive new works are partly built and partly under construction. Sewage comes to the works and passes through screens cleaned with revolving rakes in the usual manner, these rakes being operated by a water-wheel set in the sewage channel behind the screen. About half of the sewage passes to large septic tanks and the other half is treated with 5 grains of alumino-ferric per gallon, then passes through a mixing channel to twelve large sedimen-

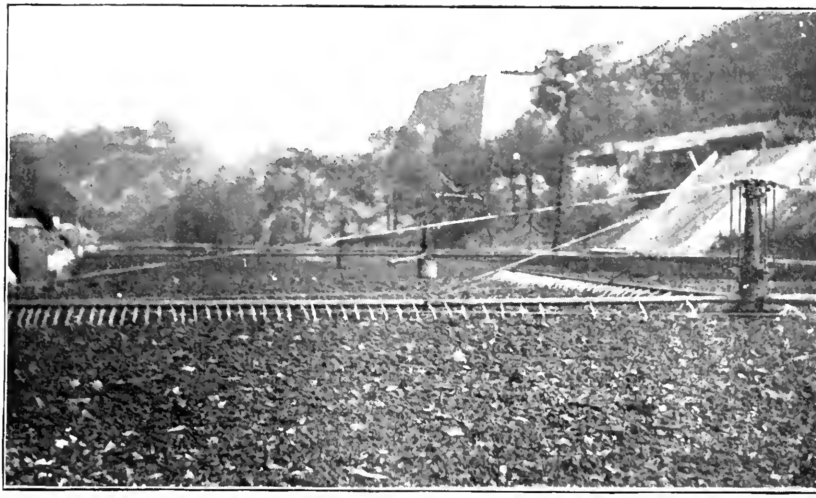


FIG. 7. SPRINKLING FILTER AT BUXTON.

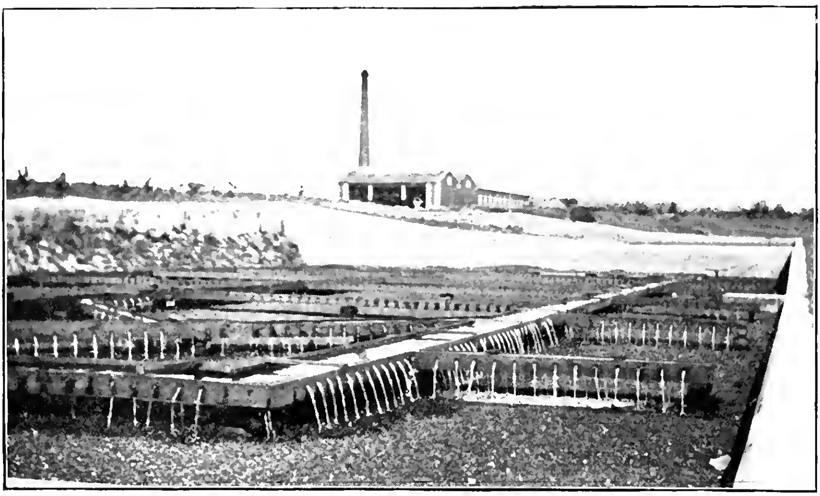


FIG. 8. SECONDARY CONTACT FILTERS AT BLACKBURN.

FIG. 9. SPRINKLING THE PRIMARY CONTACT FILTERS AT BLACKBURN.

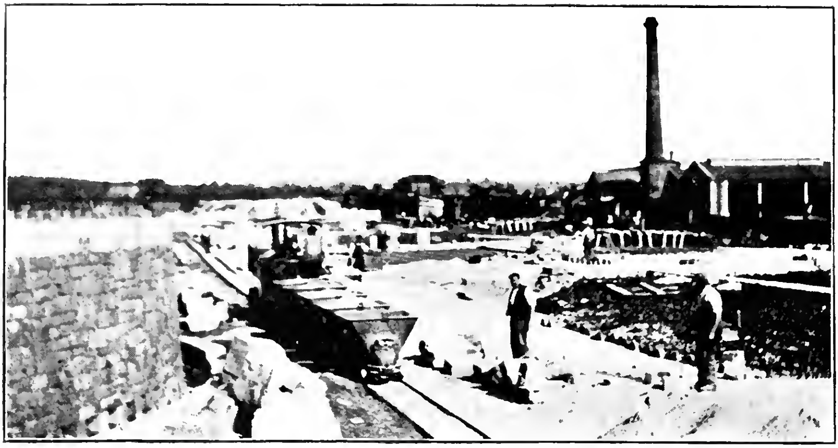


FIG. 10. CONSTRUCTING SPRINKLING FILTERS AT BLACKBURN.

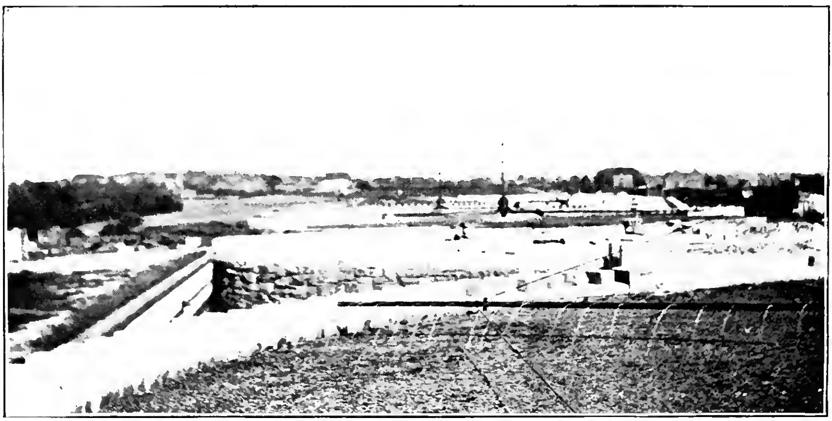


FIG. 11. A FEW OF THE BLACKBURN SPRINKLING FILTERS.

FIG. 12. SPRINKLING FILTER AT CHESTERFIELD.

tation tanks, these tanks holding about 5 000 000 gal., or a day's flow in dry weather. The septic sewage is, however, treated with a small amount of chemicals before filtration. The alumino-ferric used is made at the plant from shale taken from a quarry on the farm, and costs about twenty-seven shillings per ton. From the sedimentation and septic tanks part of the sewage passes to contact and part to sprinkling filters. I have already spoken of the contact filters, and there are either finished or in course of construction 24 sprinkling filters, 80 ft. in diameter and 9 ft. deep. These filters are very heavily built with concrete bases and heavy stone sides. The stones in the sides do not fit particularly close but, nevertheless, present the appearance of a fairly smooth cut-stone wall. At the bottom of the filters, practically touching each other, are semicircular tile pipes 12 in. in diameter in 3-ft. lengths; that is to say, the entire bottom is covered by these underdrains. These filters are not entirely separate as at Heywood, but run together at one point, that is, touch each other, but heavily walled concrete channels run around each at the bottom passing under the filters at the junction of each pair. Along one side of each set is a straight, heavy, concrete main effluent channel. The filters are constructed of graded material. On the bottom are large pieces of destructor clinker. This layer is about 1 ft. in depth and above this layer the remainder of the filtering material is broken stone, coarse at the bottom, but growing rapidly finer towards the top until at the top the pieces are not more than one-half in., or less, in diameter. This stone seems to be rather soft and the top layer appeared to be disintegrating and the filters were pooling. The effluent of these filters passes over a weir into two Dortmund-shaped tanks, 28 ft. in depth; then from these tanks it passes into the Derwent River. At the time of my visit the Dortmund tanks were covered with a scum apparently putrefying and the effluent of the sprinkling filters as it passed into the river was poor, certainly not non-putrescible, but this was due not to the fault of the method of filtration but to the method of construction of the sprinkling filters. That is to say, the filters had undoubtedly too much fine material in the upper layers, and by close construction of the sides, together with the pooling at the filter surface, the air supply was shut off. While the plant was very imposing and handsome it was not making the returns in purification that it should for the expenditure that had been made. On all the trickling filters the sewage was being distributed by re-

volving distributors. This entire plant, including the original sewage farm, had cost $1 300 000. The modern part, about $500 000, divided as follows: settling tanks, mixing house, sludge-pressing house and machinery, $230 000; contact beds, $100 000; septic tanks, Dortmund tanks and sprinkler filters, $112 000. The sprinkler filters, 80 feet in diameter, cost $5 000 each, or about $42 000 per acre.

Chesterfield is a city slightly larger than Heywood; that is to say, it contains 35 000 people, and the normal flow of sewage is 1 000 000 gal. per day. The sewage area, in distinction from the plants at Heywood and Blackburn, showed a pleasing simplicity and cheapness, but was turning out an effluent better than that at Blackburn and fully equal to that at Heywood. Nominally, there are 17 circular filters. Really, however, the bed is all in one piece without elaborate retaining walls and without concrete bottom. That is to say, the filters all run together, but there are 17 rotary distributors, the corners where the arms of the distributors do not reach simply being left unfilled with clinker in most instances. The beds varied from 5 to 8 ft. in depth. The distributors were all made in Chesterfield and not patented, but were of the usual Barker mill type. The circular areas to which the arms of the distributors reached varied from 90 to 104 ft. in diameter. The cost of the beds was about $2 125 each, or practically $40 000 for the entire area, about $12 500 per acre, this including preparation of site, distributors, etc. No chemicals are used at Chesterfield, sewage being simply screened and then passed through settling tanks having a capacity of 700 000 gal. Formerly these tanks were used as septic tanks, but as they filled with sludge they are now cleaned out regularly every three or four weeks. The plant is on the site of the borough sewage farm, started in 1879, and the present filters have been in operation six years. They are in good condition and show no signs of clogging. The material in them, largely destructor clinker, varies from 6 in. to $\frac{3}{8}$ in. in diameter. On the day of my visit the effluent was clear, with very little suspended matter, and nitrification was good, judging from the analyses shown me by the manager. Six men are employed at the works and the total yearly cost of operation including pumping is about $3 000, giving a working cost of about $9 per million gallons treated.

The following were given me as representative analyses of the Chesterfield sewage, of the effluent of the tanks and of the effluent of the sprinkling filters.

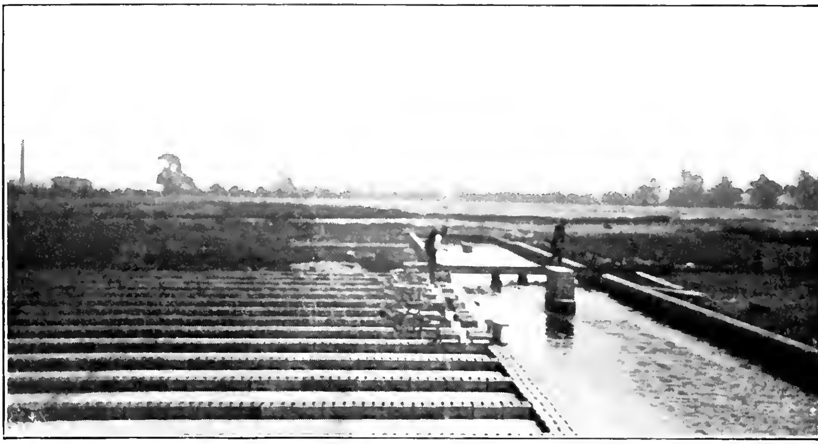


Fig. 19. Building Storm Filters at Birmingham.

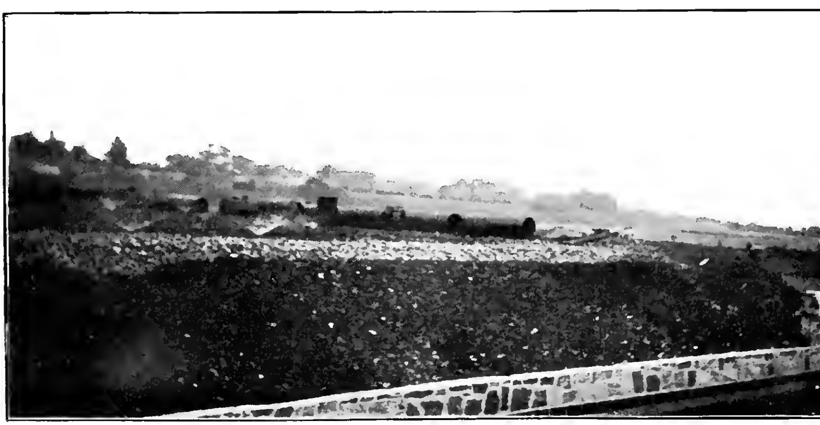


Fig. 20. Storm Filters at Birmingham.

FIG. 21. CLEANING NOZZLES: BIRMINGHAM SPRINKLING FILTERS.

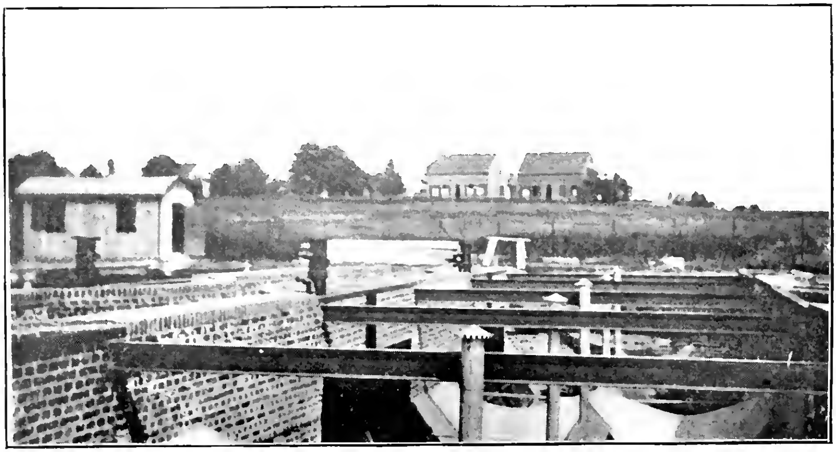


FIG. 22. IMHOFF SEPTIC TANK, ESSEN.

(Parts per 100 000.)

	Free Ammonia.	Albuminoid Ammonia.	Chlorine.	Nitrates.
Sewage	1.88	1.36	9.80	....
Effluent of tanks	1.16	0.50	8.60	....
Effluent of sprinkling filters	0.16	0.067	8.00	1.76

The sewage plant at Hanley is probably the handsomest and most striking of any that I saw during my visit to England, and, take it all in all, one of the most interesting. I believe it is practical also, in spite of what seems the almost unnecessarily costly equipment. Hanley is a city of 70 000 people, and has an average daily flow of sewage of 2 000 000 gal. and a wet weather flow at times of 9 000 000. The sewage at Hanley began to be purified about thirty years ago. About twenty-five years ago the purification was about as follows: Chemical precipitation, sedimentation and filtration through specially prepared sand filter beds, 12 in number, of about an acre each, with underdrains at the depth of 5 ft. and about 18 ft. apart. The rate of filtration of the chemically clarified sewage was about 100 000 gal. per acre daily. This was really an intermittent sand filtration scheme, preceded by chemical precipitation, and the character of the effluent was that which would be expected from such filters — entirely satisfactorily. A large volume of mine water was discharged into the sewers, together with wastes from pottery works, Hanley being a center of the pottery industry. The wastes from the mines were charged with salts of iron, the waste from the pottery works with clay, and these two bodies aided in clarification by chemical precipitation. It was not until about eleven years ago that this scheme began to be badly overworked. At that time — 1897 — a so-called purification syndicate agreed to purify all the sewage by a patent process, and their proposition was accepted by the borough council. The method of this syndicate was to sterilize the sewage and to aid precipitation by a solution of perchloride of iron in conjunction with the salts of iron and clay from the mining and pottery wastes. It is stated a carbolic solution in the form of vapor was forced into the sewage during its discharge down the carrier after chemical precipitation. It is also stated that although this thoroughly sterilized the effluent the very large amount of organic matter remaining in it, putrefied when mixed with the water in the river, sterilization being overcome by dilution. The method was abandoned and the present plan was adopted. The sewage passes through

the usual screens with automatic cleaners, then through detritus tanks with a capacity of 250 000 gal., and septic tanks with a capacity of 5 000 000 gal. There are to be $9\frac{1}{2}$ acres of sprinkling filters, 9 in acre beds and one $\frac{1}{2}$-acre bed. The acre beds, however, are practically divided by the sprinkling apparatus into four equal parts about 200 ft. long and 50 or 60 ft. wide. The construction of the beds is very handsome, brick walls and 6-in. concrete bottoms. Glazed tiles are prominent in many parts. The drains in the bottom consist of semicircular tile pipes set in concrete with the upper edges nearly flush with the concrete floors of the filters. Over these drains square brick-like tiles are placed close together, these tiles having three or four slit-like openings on top, also openings along the sides at the bottom. Over these underdrains is placed a layer of broken brick about fist-size, and above this layer 5 ft. in depth of broken saggers, the pieces being $\frac{3}{8}$ to $\frac{1}{2}$ in. in diameter. This is very handsome material, richly colored and, on the whole, the beds are the handsomest of any that I visited in England. The distributing device is as follows: On the side of each filter and section a track is laid and also a channel or trough into which sewage is delivered. Stretching over each section of the filter is a heavy iron distributor, a bridge-like structure operated by means of an endless wire rope coming from a power-house at the end of each filter, the power used being a $1\frac{1}{2}$ h. p. motor in each power-house, and the electric power is supplied by the electric plant owned by the borough. The endless rope turning a wheel causes the distributor to move slowly from one end of the filter to the other. When reaching the end, an automatic device in the power-house comes into play and the belt turning the wheel, around which passes the endless rope, is slipped upon another gear moving in the opposite direction. This reverses the direction in which the wheel turns and the distributor is moved across the bed in a reverse direction. The sewage is siphoned from the channels or troughs along each section into the pipe in the distributor. From this pipe it is delivered through many small openings in the bottom upon dash plates which sprinkle it on the surface. When reaching the end of the filter a projecting arm moving a lever shuts off the sewage and the distributor travels back to the other end of the bed without delivering sewage. That is to say, sewage is distributed only when the distributor is traveling in one direction, every alternate journey being an idle one. As it takes three minutes for the distributor to travel across the bed, each point of the

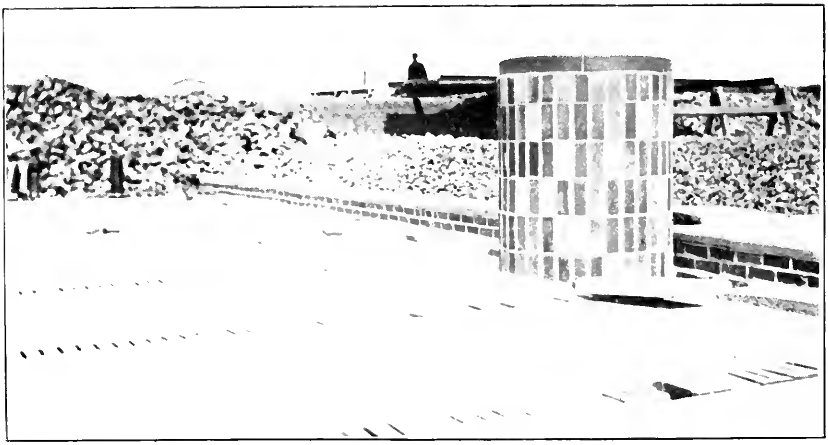


FIG. 13. UNDERDRAINS AT HANLEY.

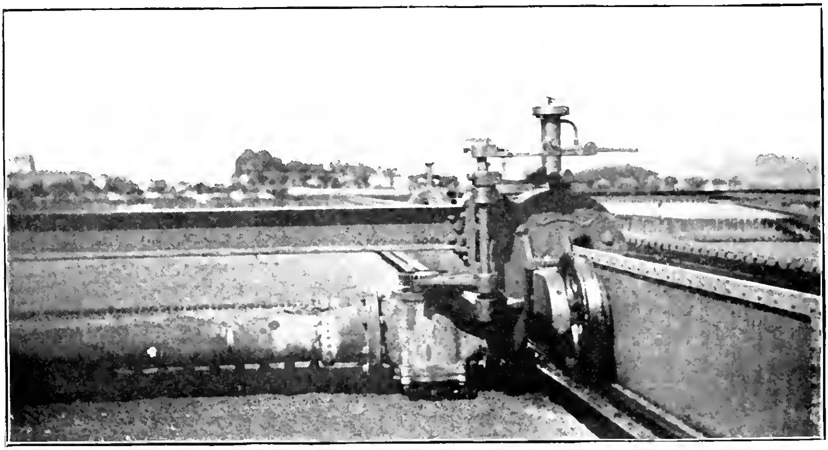


FIG. 14. THE HANLEY DISTRIBUTOR.

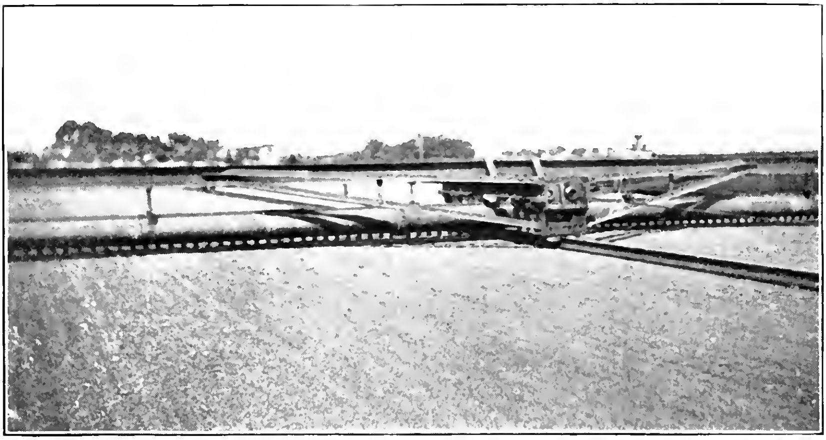


FIG. 15. THE HANLEY DISTRIBUTOR.

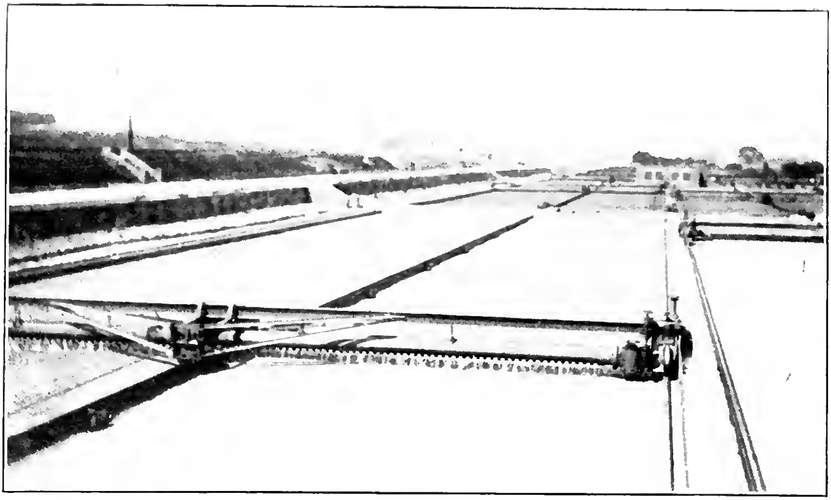


Fig. 16. Hanley Distributor and Filter Beds.

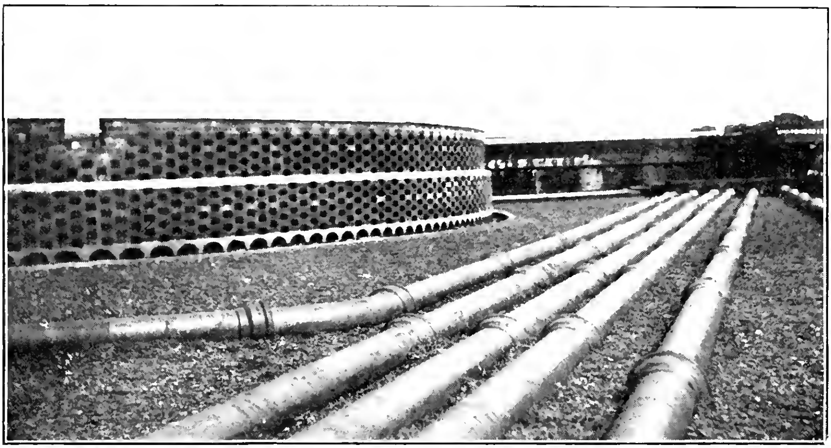


Fig. 17. Horwich.

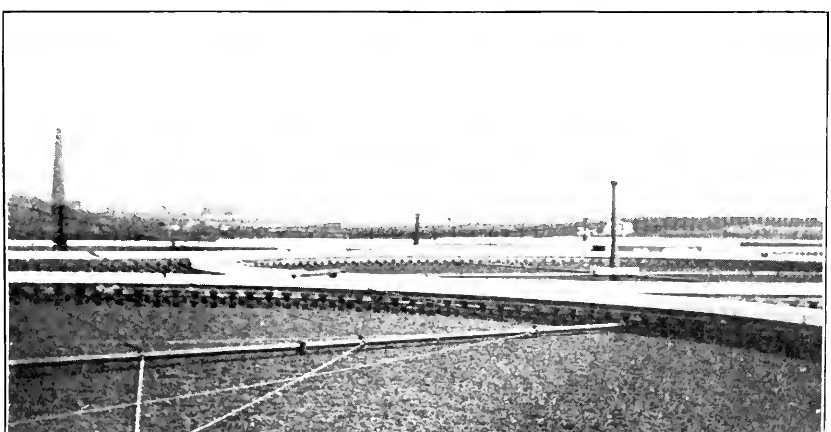


Fig. 18. Horwich.

filter rests 6 minutes after receiving sewage before it is flooded again. The sewage applied to these filters was practically free from suspended matter and the effluent was very handsome on the day of my visit. It was as clear practically as the effluent of a good sand filter. The rate of filtration is said to average 750 000 gal. per acre daily. The filters are said to have cost $27 500 per acre, and the sprinkling apparatus $6 000 per acre. The entire cost of the as yet unfinished plant, including detritus and septic tanks, was estimated to be $375 000, and the estimated capacity is 9 000 000 gal. per day, or about $42 000 per million gallons daily capacity. The actual cost I was assured, however, will be in the neighborhood of $500 000, or $55 000 per million gallons. The cost of running the distributors is not counted, as the electric power is supplied by the borough plant, but it is evident that the Fiddian distributor could, under most conditions, be used in these rectangular beds. The filters were operating at a rate probably not greater than 600 000 gal. per acre daily at the time of my visit, the sewage applied was practically free from suspended matter and the effluent resembled a good sand filter effluent — clear, odorless, colorless and highly nitrified. In order to successfully operate trickling filters constructed of material as fine as that at Hanley without clogging, a very clear sewage must be applied. The Hanley sewage was of the required character, and it is probable that the mine drainage and pottery wastes still aid in clarification in the septic tanks.

The following analyses are given in a recent Hanley publication as representative of the sewage before and after treatment in the septic tank and the effluent of the rectangular filters.

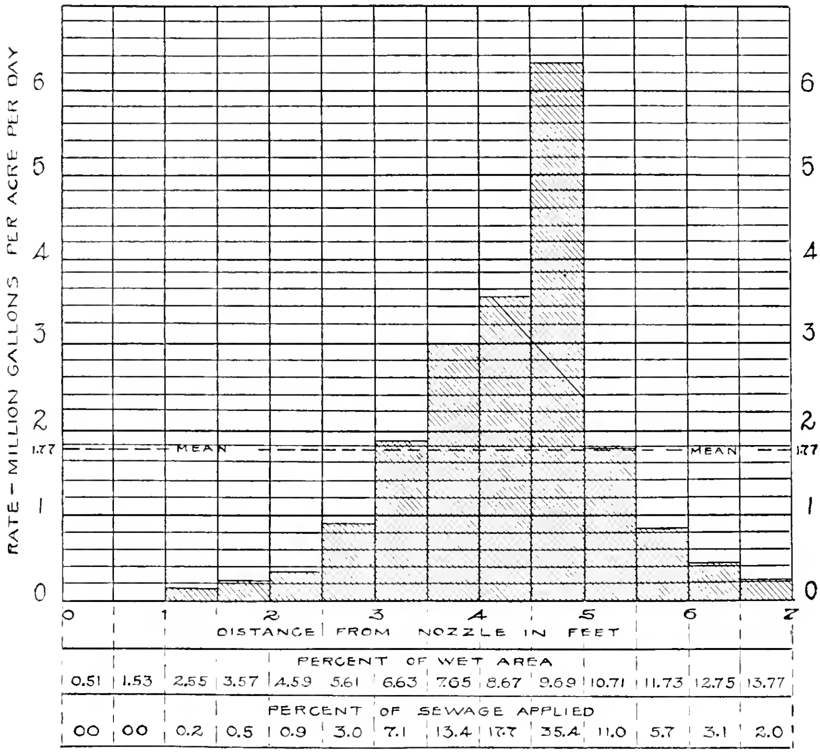
ANALYSES OF SEWAGE AND EFFLUENT.

(Parts per 100 000.)

	Solids.			Ammonia.		Chlorine.	Nitric Nitrogen	Oxygen absorbed in 4 Hours at 80° Fahr.
	Total.	In Solution.	In Suspension	Free.	Albuminoid.			
Raw sewage..	188.3	125.4	62.9	2.109	0.765	8.9	0.00	3.854
Septic sewage	109.7	105.3	4.4	1.820	0.270	8.7	0.00	1.725
Effluent of filters	112.4	112.0	0.4	0.081	0.029	8.5	1.75	0.273

Birmingham at the present time passes its sewage through detritus tanks with a capacity of 5 000 000 gal. and septic tanks

RATES OF FILTRATION UPON DIFFERENT PORTIONS OF SURFACE COVERED BY A BIRMINGHAM SPRINKLER UNDER 6 FOOT HEAD WITH THE NOZZLE ON SURFACE OF FILTER



with a capacity of 7 000 000 gal. Practically all the sewage is cared for upon trickling filters, although some still goes to the 3 000-acre farm. Near the septic tanks are 4 acres of so-called storm beds in use all the time, however, and 30 acres of storm beds are being built. These are all sprinkler filters 6 ft. deep, filled with clinker, but with a few inches of broken stone on the surface. All beds have concrete bottoms. In the storm beds the tile underdrains are several feet apart, with large cobblestones between, while in the sewage beds proper, tile underdrains cover the entire bottom. At the area of sprinkler filters five miles below the septic tanks and storm filters, all the beds are of broken stone of the same grade practically throughout the entire depth, the pieces being from $\frac{3}{4}$ to 2 in. in diameter, and the sewage is applied — generally under a head of 6 ft. — by the well-known Birmingham sprinkler nozzles inserted in surface pipes. The beds are 1, 2 and 3 acres

in area, and all have heavy side walls. These beds cost $30 000 per acre. The septic sewage before filtration passes through large Dortmund tanks at this lower area, and after filtration through somewhat similar tanks. At the time of my visit the final effluent was much inferior in appearance to that at Heywood, Chesterfield, Hanley, Buxton and other places, although such analyses as I have seen show it to be generally high in nitrates and non-putrescible. The following analyses of Birmingham sewage and effluent are taken from the Royal Commission report.

ANALYSES OF SEWAGE AND EFFLUENT.

(Parts per 100 000.)

	Solids in Suspension.	Ammoniacal Nitrogen.	Albuminoid Nitrogen.	Nitrates.
Raw sewage........	48.4	3.67	0.98	....
Septic sewage.......	13.8	6.39	0.71	....
Final effluent.......	....	2.86	0.29	2.11

The rate of operation of the filters is practically 900 000 gal. per day. Twenty-three acres are in operation here and seven acres are being constructed. The cost of maintenance of the Birmingham complete works is about $40 per million gallons treated.

At Wilmersdorf, Germany, I took my last look at a sprinkling filter plant: 56 sprinkling filters, 60 ft. in diameter, constructed entirely of coke, the sides being simply large pieces of this material. The sewage first passes through septic tanks, then to these filters; settling basins follow and then sand filters. The sand filters at Wilmersdorf are called "Chorley Filters," as similar sand filters are in use at Chorley, England. A recent Chorley report states that intermittent sand filtration was "discovered" there a few years ago. The Wilmersdorf plant is eighteen miles from Berlin in a large sandy plain with very few houses in sight. The sewage, about 5 000 000 gal. daily, travels eighteen miles to the disposal area. A septic tank was being cleaned on the day of my visit and the sludge was so thick that sewage was being run in to liquefy it in order that it might be forced through the pipes leading to the sludge basins. Men were down in the basin stirring the sludge with poles. This plant is for a population of 60 000 now and is to be increased to care for 260 000. The final effluent was dark but odorless and was running into the Tetlow canal very close to well-patronized beer gardens. This plant has cost about $500 000 up to date.

Preliminary Treatment.

Every sewage plant that I visited had a more or less expensive system of preliminary treatment of the sewage, generally chemical precipitation with alumino-ferric or lime. At Heywood, Salford, Buxton, Rochdale, Blackburn, Chorley, York, Bradford, Leeds, Sheffield, Wolverhampton and other places, screens, chemicals, generally alumino-ferric, lime or iron salts, and ample settling tanks before filtration are employed. At Bradford and Leeds this is the entire treatment at present, except for a few small outlying sewage farms and trickling filters, and filtration is hardly being considered, although Bradford has purchased land for the erection of filters at some future time. Leeds, on the other hand, is building a large and improved precipitation plant. At other places, as at Manchester, Chesterfield, Accrington, Birmingham and Horwich, screens and settling or septic tanks are in use. At none of the places that I visited was any attention being paid to septic tank patents. At many of the places the sludge was pressed, at others lagooned until dry enough to handle and then carted away to farms, shipped in canal-boats to farms, dumped into lowlands, abandoned coal mines, or buried in land. At a few places it was being burned in destructors, and at Bradford preparations were being made to use it in the production of gas. At none of the places I visited did I find it being plowed in. At York, the sod and soil are stripped from a field and eight or nine thousand tons of sludge are buried yearly after pressing; then the sod and soil are replaced. There is at York at the present time a field of sludge 9 to 14 ft. deep and 9 acres in area, the accumulation of the past five years. Four men are continually employed at this sludge burying, and a handsome field of a somewhat higher grade is the result. At Birmingham, plowing in has been abandoned as thirty or forty acres were required for this purpose yearly and crops were poor. A large new area, many acres in extent, is now available, and to this the sludge from the septic tanks flows and is lagooned. It is a three-cornered area inclosed by railroad embankments. Sections are divided off by low earth embankments and gradually filled with the constant flow of black, liquid, but odorless sludge. Mr. Watson, the engineer of these works, states that he is not only disposing of sludge effectively and without offense in this manner, but also is making valuable land. In Germany, screening plants seem to have reached a high degree of efficiency, double and triple sets of screens being not uncom-

mon with the self-cleaning apparatus moved by power generated by water-wheels in the sewer.

Septic Tanks.

There is a general opinion abroad that septic tanks do not destroy even under the best conditions more than 25 per cent. of the organic matter entering them. At Hanley and Birmingham they say not more than 10 per cent. It is evident that at many so-called septic tank installations, the detritus tanks collect a large part of the organic matter. At Birmingham, for instance, the detritus tanks hold $\frac{5}{7}$ as much as the septic tanks, and, according to Mr. Black, the manager of these works, more than half the sludge is caught in these detritus tanks and removed from them. This sludge does not go to the septic tank sludge area. The greater the number of septic tanks that I inspect the more I am convinced that tanks for sludge only are by far the most practical. Such tanks may be small in comparison with the daily flow of sewage, and in them the organic matter has nearly an equal chance of change and destruction as in larger septic tanks and the sludge becomes concentrated in a shorter period of time. That is to say, a given weight of sludge contains a much less percentage of water, thus diminishing the volume of sludge greatly. At Essen, Germany, I was interested in the septic tank of the Imhoff Company. This Imhoff tank is simply a combination of large circular tanks with conical bottoms, the upper circular portions being connected by a straight channel through which the sewage flows. The matter in suspension in the sewage settles and passes into the septic tanks proper, where it remains for a matter of six weeks, while the main flow of sewage passes through quickly.

Odors of Septic Sludge.

I believe that it is pretty clear at the present time, judging from experience at home and abroad, that whether the sludge from septic tanks is offensive or not depends entirely upon the character of sewage entering these tanks, together with method of operation. Speaking broadly, the sludge of domestic sewage may, unless exceedingly old and well digested, be very offensive. It occasionally may not be, however, for reasons that cannot be explained. Certain wastes from manufactural industries may lessen the odors developed in septic tanks, and septic sludge and other wastes may increase them. I believe the entire lack of odor of the sludge from the Birmingham septic tanks to be due

largely to the iron and copper salts coming into the sewage from the industries of Birmingham. When this sludge is spread on the ground it appears to be poisonous to vegetation. Nothing, not even weeds, will grow in it unless it is mixed with other soil. At other places where brewery or wool wastes enter the sewage, the septic sludge may be, generally speaking, quite offensive. I can say from my own observations abroad, I believe that well digested septic sludge has generally much less odor than sludge from detritus and chemical precipitation tanks, and that the odor from precipitation and settling tanks is fully as great as that from most septic tanks.

Automatic Apparatus.

Nearly all trickling filters in England are operated intermittently. That is to say, the sewage is applied for an hour or more; then an equal period of rest ensues. There are, of course, filters, such as those at Hanley, where a more frequent period of rest is given, and at other places a longer period of operation. In one or two places, while the average rate of filtration was stated to be 1 000 000 gal. per acre daily, the filters were really operated at a rate of 2 000 000 gal. for 12 hours, then a second set operated for the remaining 12 hours of the day. The changing of the flow of sewage from one revolving sprinkler to another is generally attended to by hand, but in many places there are automatic devices in use. These devices were out of order at a number of places at the time of my visit. At most beds there was an ample supply of men working in the vicinity of these devices most of the day, and probably attention by hand would have been, to say the least, equally as efficient. At nearly all trickling filter plants in England some form of automatic distributor is in use, generally the Barker wheel type, the Fiddian, or modifications of these two, Birmingham and Salford being the only two large places at which I found sprinkling nozzles in use. When I started I was strongly inclined to believe that the use of nozzles was the common-sense method. I have become convinced, however, that under English conditions distributors of the Fiddian, Simplex or Hanley type are by far the best. It is evident that filters operated with this type produce better effluents, other things being equal, per unit of filter surface, and every square inch of filter can be used. By sprinkling nozzles operating under a constant head, as at Birmingham and Salford, as can be seen from observation of these areas, and as has been shown by experiments at Lawrence and elsewhere, only

about fifty or sixty per cent. of the filter is really used. That is to say, if 2 000 000 gal. of sewage are applied daily to an acre bed by means of nozzles, a considerable area will operate at a rate of five or six more million gallons per acre daily, while a portion will operate at a rate of half a million gallons or less. There is little or no spreading of the sewage as it passes through filters of clinker, coke or broken stone. In other words, if the sewage was as perfectly distributed over the Birmingham filters as over the Hanley, Heywood and other filters, the area of these filters might perhaps be reduced 50 per cent., the cost of construction be not much more than half as great, and the same purification result be achieved. Even in this country, I believe, perfect distribution, even if the form of distributor necessitates covered filters for good winter work, may in the end be the practical method of construction and operation. Sprinkling nozzles operating under a variable head improve distribution, but it is evident that nozzles call for constant attention. The men tramping over the Birmingham filters, one to every one and one-half acres, keeping the nozzles clear, have no sinecure. They are about the wettest objects at the plant. In cold American winter weather it would be a job requiring much fortitude. Distributing orifices can be much larger when the application is intermittent than when it is continuous, thus insuring less frequent clogging, and this is certainly one of the advantages of the intermittent operation of sprinkling filters. The Fiddian distributor I judge might be almost free from clogging, the sewage rising and emptying from the hod-shaped holders into the divisions of the wheel, the weight of the sewage turning the wheel and causing the distributor to roll around circular beds or forward and back on rectangular beds. All of these revolving Barker mill sprinklers or Fiddian distributors can work under a very small head. At one place I found revolving sprinklers working under a head of 4 in. Take it all in all, intermittent-continuous is the best designation of these filters. They are all percolating filters, but so is a sand filter; some have sewage sprinkled upon their surface, but so do some contact filters.

The Material in Contact and Sprinkling Filters.

In regard to contact filtration, I believe that all extended investigation proves that good work and long life of the filter depend on effective preliminary treatment of the sewage, more effective than the present Manchester treatment. I consider Dr. Fowler the foremost English authority on sewage purification,

but I very much doubt his ever accomplishing as satisfactory results with the present Manchester plant as would be possible if chemicals were used. Certainly the plant can never give results equal to the best plants at which the trickling filter is the main feature of the purification scheme.

There has been much said of late years of Dibdin's slate contact filters. The Royal Commission, in its latest report, however, states that from their own observations the results of these contact filters resemble the results of septic tanks rather than filtration results. In this connection I wish to call attention to the fact that a filter of roofing slate with regular ½ in. spaces between the slates was operated at Lawrence nearly eight years ago, and in the report of 1901 it was stated that the action in this filter was anaërobic rather than aërobic.

The filtering materials used most largely in contact and trickling filters are coke, clinker and broken stone, although burnt ballast I found being used in one or two places. There is no doubt that in contact filters coke and clinker give better results than broken stone, and the finer the material the better the purification of the applied sewage. If operating contact filters and removing material every few years to wash out the matters retained in them from the applied sewage is cheaper and more efficient than chemical precipitation, as Dr. Fowler states, there seems to be a wide opening for the use of contact filters as a preliminary treatment of sewage after sedimentation at purification plants. In trickling filters all grades of material are used. I found filters operating with pieces of clinker half a foot in diameter and the entire filter made up of this material, and at other places, filters with material not over ¼ or ½ in. in diameter throughout the entire depth, and at other places graded material. The best results were universally given, I believe, where the material was practically of the same grade throughout the greater depth of the filter with coarse material over and around the underdrains. Other things being equal, the finer and the rougher the material the better the effluent. At places where materials were mixed to any great extent, different grades of broken stone or different grades of coke, more or less trouble from clogging was occurring or had occurred. That is to say, just as we have found at Lawrence, we can run a good trickling filter with coarse stone, most of the pieces 2 in. in diameter; or a good trickling filter with fine stone, most of the pieces ¾ or 1 in. in diameter, but if the two grades are mixed, the open space is more completely filled and clogging may ensue. On the whole it

seems reasonable to assume that material of the grade used at Birmingham, for instance, is more practical, and under good conditions would give better results, than the grade used at Heywood, this depending, however, to a considerable extent on the degree of efficiency of preliminary treatment given the sewage. The Hanley material, except when receiving a sewage as beautifully clarified as that at Hanley, would prove altogether too fine.

Use of Chemicals.

The reason that chemical precipitation is employed so largely where modern filters are in use in England is that by such chemicals and sufficient sedimentation a liquor can be produced containing only about one third as much suspended matter as the same sewage after passing through ordinary septic or settling tanks. To be sure the sludge produced is almost three times that remaining after successful septic tank treatment, but a clear liquid is of the utmost importance in obtaining good and economical results from many English contact and sprinkling filters. The Royal Commission estimate that the sludge from chemical treatment of a unit volume of sewage will require nearly three times as much land per year for sludge burial as the sludge resulting from the same unit volume of sewage submitted to septic tank treatment, and that the cost for labor in this respect will be practically twice as great for the chemical as for the septic tank treatment. The cost per million gallons of chemical precipitation treatment, including loan charges, they estimate to be about $17, and of septic tank treatment, $8.50 per million gallons; that is, for these preliminary treatments only, omitting further purification. They estimate, however, that the rate of operation of trickling and other filters may be twice as great when receiving a sewage treated chemically as when operating with the same sewage treated in septic tanks. This means, of course, a reduction in filter area when the chemically clarified sewage is applied and nearly equalizes the cost. Including filtration loan, etc., the cost per million gallons is believed by the Royal Commission to be about $25 for chemically clarified sewage and $22 for sewage from septic treatment, this with open septic tanks. These costs are calculated from the results of various plants under observation by the Royal Commission for a number of years and assume practically perfect conditions. I have no hesitation in stating, however, that actually the majority of plants in England to-day would figure out a much greater cost

per million gallons than this. In the majority of cases the effluent produced at this cost is, perhaps, stable; that is, will not undergo secondary decomposition but generally contains, as is necessary and economical, practically as much suspended matter as in the liquid applied to the filters. Generally such effluents should be treated further by sedimentation and straining or filtering, if a clean as well as a non-putrescible effluent is desired.

Cost of Precipitants per Million Gallons Treated.

Alumino-ferric, a crude sulphate of alumina, is the precipitant most in favor at the present time in England, although, of course, lime and other precipitants are also used. At a number of plants that I visited, such as Chorley, Blackburn, etc., this precipitant was not bought but made at the plant. At other places, such as Buxton, lime is obtained very cheap owing to the plant being in the neighborhood of lime works, one almost overhanging the plant, as shown in the picture; and chemical precipitation was further cheapened at Buxton by the use of a constant stream of water piped from an abandoned colliery containing iron salts in solution, this small stream running constantly into the sewage just below the point at which lime was added. Owing to these facts the great variation in cost of chemicals may be observed. At Heywood the cost is $6.50 per million gallons; at Rochdale, $7.00 per million gallons, but at Chorley, Buxton and Blackburn, $3.10, $1.12 and $2.60 per million gallons, respectively.

Strength of Sewage, Etc.

The average English sewage is not much, if any, stronger than that used at the Lawrence Experiment Station. For the last fourteen years the results of hundreds of analyses show the experiment station sewage to average about as follows:

(Parts per 100 000.)

Free Ammonia.	Albuminoid Ammonia.	Chlorine.
4.25	0.75	9.25

Comparison of the results of many analyses of rather strong English sewage given in following tables follows, these analyses being taken from the Royal Commission report. In many English cities and towns the small volume of sewage per inhabitant is partly due to the not uncommon continuance of the old pail system in sections of these towns and cities.

The effluents of English filter plants do not differ from effluents produced by various filters at the Lawrence Experiment

Station. The effluents of properly constructed and operated contact and sprinkling filters at Lawrence are of the same quality as those of the best English contact and trickling filters, and poor effluents are the rule in England as well as at the station when the filters are not constructed according to the best designs. Data in regard to rates, clogging, etc., are very similar.

Tables appended to this article are either taken directly from the fifth report of the Royal Commission on Sewage Disposal or made up from figures given in that report. Table No. 1 illustrates the character of sewage of different English cities, the strength of this sewage, the results of septic tank treatment and the ordinary disposition of sludge. Table No. 2 reports the results of chemical precipitation of the sewage of certain English cities. Table No. 3 shows the results of various percolating filters, the method of distribution, analysis of final effluent, etc. Table No. 4 is copied directly from 'the report of the Commission and shows their estimate of the cost per million gallons of treating upon sewage farms the "dry weather flow" of the sewage of these cities and towns. Table No. 5, taken also directly from the report, gives their estimate of cost per million gallons of various preliminary treatments of sewage followed either by contact or percolating filter treatment.

TABLE No. 1.

TREATMENT OF SEWAGE IN SEPTIC TANKS.

Place.	Population.	System of Sewage.	Dry Weather Flow of Sewage. (Million Gallons.)	Nature of Sewage.	Analysis of Sewage. (Parts per 100 000.) Ammoniacal Nitrogen.	Analysis of Sewage. Albuminoid Nitrogen.	Analysis of Sewage. Suspended Solids.	Rate of Flow through Tanks (expressed in time taken to fill tank in dry weather).	Analysis of Septic Tank Liquor. (Parts per 100 000.) Ammoniacal Nitrogen.	Analysis of Septic Tank Liquor. Albuminoid Nitrogen.	Analysis of Septic Tank Liquor. Suspended Solids.	Tanks Cleaned.	Method of Disposing of Sludge.
Accrington...	46 300	Combined.	1.18	Strong domestic	5.18	0.68	43.3	42 hr.	5.03	0.34	19.4	Every 4 to 6 mo.	Lagooned and sold when dried.
Birmingham .	865 701	Combined and partially separate.	22.0	Trade sewage.	3.67	0.98	48.4	10–12 hr.	6.39	0.71	13.8	Septic tanks periodically.*	Buried in adjacent ground.
Leeds	450 142	Combined.	16.0	Trade sewage.	2.60	0.80	61.4	24 hr.	1.73	0.47	21.7	End of 2 yr.	Lagooned.
Manchester ..	575 000	Combined.	25.3	Trade sewage.	2.27	0.51	35.0	15 hr.	2.74	0.37	10.8	.....	Sent to sea.
Rochdale	52 000	Combined.	1.31	Domestic, with wool washings.	4.16	1.29	36.7	30 hr.	3.74	0.67	5.3	Every 6 mo.	Pressed and sold to farmers.
Sheffield.....	400 000	Combined.	14.5	Trade sewage.	2.61	0.76	50.2	24 hr.	1.96	0.37	..	At long intervals.	Lagooned.
York........	80 000	Combined and partially separate.	4.25	Domestic, with trades waste.	2.58	0.82	21.2	26 hr.	2.86	0.40	5.3	After 21 mo.	Lagooned.

* Roughing tanks once a week.

TABLE No. 2.

Chemical Precipitation followed by Settlement.

Place.	Nature of Sewage.	Analysis of Sewage. (Parts per 100 000.)		Precipitant used and Quantity added in Grains per Gal.	Analysis of Precipitation Liquor. (Parts per 100 000.)		Method of Disposing of Sludge.
		Ammoniacal Nitrogen.	Albuminoid Nitrogen.		Ammoniacal Nitrogen.	Albuminoid Nitrogen.	
Chorley . .	Domestic.	4.20	1.01	Alumino-ferric, 9.0 grains on average flow.	3.82	0.55	Pressed and sold to farmers.
Heywood	Domestic, with trade waste.	3.37	0.83	Alumino-ferric, 8.0 grains on average flow.	1.99	0.42	Pressed and taken by farmers.
Leeds. . . .	Trade sewage.	1.95	0.68	Lime, 3 grains on average flow.	1.84	0.32	Lagooned.
Rochdale	Domestic, with wool-scouring liquor.	4.16	1.29	Alumino-ferric, 7.3 grains; vitriol, 4.7 grains, on average flow.	4.20	0.66	Pressed and taken by farmers.
Sheffield .	Trade sewage.	2.61	0.76	Lime.	1.09	0.15	Lagooned.
York	Domestic, with trade waste.	2.58	0.82	Alumino-ferric, 5.7 grains; lime, 4.3 grains, on average flow.	2.63	0.54	Pressed and buried under thick layer of soil.

TABLE No. 3.

PERCOLATING FILTERS.

Place.	Material used in Filters.	Depth of Material.	Distribution.	How Liquid is Delivered to Filter.	Analysis of Final Effluent (Unsettled). Ammoniacal Nitrogen, Hourly.	Albuminoid Nitrogen, Hourly.	Nitrates, Hourly.	Condition of Filters.
CRUDE SEWAGE: Leeds.	Clinker.	10 ft.	Tipping troughs.	Continuously.	...	...	...	Clogged after 1 month's work.
SETTLED SEWAGE: Leeds.	Coke.	9 ft. 6 in.	Sprinkler.	Continuously.	...	...	...	Unchanged after 1 year.
SEPTIC TANK LIQUOR: Accrington.	Coke or clinker.	9 ft. 3 in. to 7 ft.	Sprinklers.	Continuously.	1.07	0.27	2.24	Good after 4 to 8 years.
Birmingham.	Granite, quartzite, slag, etc.	6 ft.	Nozzles, etc.	Continuously.	2.86	0.29	2.11	....
Rochdale.	Coke.	9 ft.	Sprinkler.	Continuously.	...	...	...	Good after 7 years.
York.	Clinker, coke, slag, or broken brick.	6 ft. 6 in. by 7 ft. 8. in.	Sprinkler.	Continuously.	0.10	0.07	2.25	Good after 4 and 6 years.
PRECIPITATION LIQUOR: Chorley.	Sand, polarite, and gravel.	3 ft.	By fine material.	Intermittently.	1.07	0.09	2.35	Good after 12 years

TABLE No. 4.

FARMS WHICH WERE UNDER CONTINUOUS OBSERVATION BY OFFICERS OF THE COMMISSION FOR OVER TWO YEARS.

Place.	Population Draining to Farm.	Dry Weather Flow of Sewage in Gal. per 24 Hr.	Net Cost of Treating the Sewage per Million Gal. (including loan charges), based on the Dry Weather Flow.	Net Annual Cost of Treatment per Head of Population Draining to Farm, including Loan Charges.
Leicester	197 000	7 250 000	$28.15	$0.37
Croyden (Beddington)	100 000	4 000 000	26.85	0.38
Cambridge	50 000	2 250 000	11.35	0.18
Aldershot Camp	20 000	1 000 000	9.50	0.16
Rugby (high level)	6 000	300 000	7.40	0.12
Altrincham	18 000	800 000	5.80	0.08

TABLE No. 5.

COST OF PURIFICATION PER MILLION GALLONS (DRY WEATHER FLOW).

Preliminary Process.	Contact Beds.			Percolating Filters.		
	Total Cost of Preliminary Treatment.	Total Cost of Filtration Process.	Total Cost of Complete Treatment.	Total Cost of Preliminary Treatment.	Total Cost of Filtration Process.	Total Cost of Complete Treatment.
Quiescent settlement, with chemicals	$17.20	$10.95	$28.20	$17.20	$7.85	$25.00
Continuous flow settlement with chemicals	15.50	16.15	31.70	15.50	9.00	24.60
Quiescent flow settlement without chemicals	9.90	22.90	32.75	9.90	10.45	20.40
Continuous flow settlement without chemicals	7.75	27.75	35.50	7.70	10.23	20.90
Septic tanks	8.60	27.75	36.45	8.60	13.15	21.75

Cost per million gallons of land treatment on good land with cropping, $15.25.

DISCUSSION.

PROF. LEONARD P. KINNICUTT. — I consider myself as most fortunate in being able to be present this evening, and I wish first of all to congratulate Mr. Clark on his presentation of the subject. He has certainly given a very clear description of the plants visited by him during the past summer, and has shown us a remarkable series of slides. These plants are the most representative of modern sewage practice, and emphasize what is being done in Europe, and what may be gained by a careful study of the methods there employed. Europe is certainly greatly indebted to the work done by the Massachusetts State Board of Health, and we on the other hand should not be loath to acknowledge our indebtedness to the workers in England and on the Continent. As we all know, the contact bed and the bacterial percolating filter originated and were first brought into practical use in England, and, as Mr. Clark has shown, to study these methods in their fullest development, we still have to cross the ocean. The method of distribution of the sewage, especially on percolating beds, is one of very great importance, and I was particularly interested in what Mr. Clark had to say on this subject. I certainly agree with him that sprinklers give a very much better and more even distribution of clarified sewage than any of the nozzles now in use.

Sprinklers, however, as Mr. Clark says, could not be used in winter in New England with uncovered beds; but I am not sure that I quite agree with his tentative proposition of the possible advantage of covered filters with sprinklers over uncovered beds with nozzle distributors. It is, however, a point deserving very careful study.

In his description of the various plants, one of the most striking points is the carefulness and thoroughness of the construction of English plants, and the amount of money that is expended in what we are apt to consider non-essentials. Yet I think something can be said in favor of the thoroughness of English construction which gives even to a sewage plant a finish which attracts attention.

Of all the plants visited by Mr. Clark, the two which interest me the most, and which I visit and study every time I am in England, are the plants at Birmingham and Manchester, the best representatives, in my opinion, of the two methods of bacterial treatment, namely, percolating filters and contact beds. And I think from what Mr. Clark has said that he agrees with

me that the present trend of opinion in England is in favor of the percolating filter method of treatment, though much can be said in support of Dr. Fowler's statement regarding the cost of treatment by these two methods.

My visit to England this last summer was made to study the question as to the best method for clarifying sewage and for the disposal of the suspended matter. It seems to me that we do now know how clarified sewage can be treated so as to obtain non-putrescible effluents, but that much remains to be learned regarding the removal and subsequent disposal of the suspended matter.

In my study of this subject I visited and studied the hydrolytic tanks at Hampton, the Dibdin slate beds at Devizes, the large sludge basin at Birmingham and the experimental septic tanks of Dr. Dunbar's at Hamburg. The hydrolytic tanks at Hampton were constructed under the supervision of Dr. W. Owen Travis, the chief advocate of what is now known as the Hampton Doctrine. The belief of Dr. Travis and of his co-workers, among whom Mr. J. H. Johnson deserves special mention on account of his brilliant experimental work, is that the purification of sewage is not essentially a bacterial action, but is a physical process rendering the so-called soluble organic matter in sewage insoluble, namely, changing soluble colloids into insoluble colloids; and that bacterial action in sewage treatment is practically limited to the decomposition of the solid organic matter deposited in tanks, or deposited and absorbed by bacterial beds.

The results accomplished at Hampton and in the new hydrolytic tanks at Norwich, England, are certainly of such a character that they cannot fail to attract attention. Personally I believe that Dr. Travis's views will have a decided influence on future sewage treatment.

Dr. Dibdin's slate beds at Devizes, at High Wycombe and at Trowbridge are the visible results of Dr. Dibdin's belief that in the purification of sewage anaërobic action is unnecessary and that septic tanks render the treatment of sewage more difficult and offensive. There is no question that excellent results can be obtained from slate beds as a preliminary treatment, as is shown by the report of Dr. Fowler on the beds at Devizes; and from my own personal observations I was convinced that the sludge obtained by this process was of an entirely different character from the sludge of the septic tank, resembling very closely the sediment washed out from percolating filters.

The sludge basin at Birmingham is perhaps the most interesting and astonishing sight in connection with sewage treatment that I saw during the past summer All of the sludge from the second series of septic tanks at Birmingham, which is the largest installation of septic tanks in the world, is pumped to a large triangular area, two acres in extent, surrounded by earthern embankments, two of which are 20 ft. high, the other 10 ft. high. Into this area is pumped daily about 800 tons of sludge, the greater part of which comes from the second series of septic tanks, the sludge of which is removed on the average once a month, but a portion is practically fresh sludge from the first series of septic tanks. In this area, which is now covered to the depth of about 8 ft. with sludge, rapid decomposition of the solid organic matter is taking place, as is shown from the amount of gas being continually evolved; yet with all this decomposition no odor is perceptible when standing on the banks enclosing the area. Why this is so it is difficult to explain; possibly it is the character of Birmingham sewage containing, as it does, a larger amount of copper sulphate than any sewage which I have studied. Mr. Watson, however, has another theory, which I cannot, at this time, attempt to explain, though, like all Mr. Watson's ideas, it is deserving of the most careful attention.

Dr. Dunbar is well known to you all from his experiments, not only on sewage treatment, but from his brilliant work in various branches of sanitation. His experiments with his experimental septic tank receiving all the sewage from Hamburg's Isolation Hospitals has resulted in producing some of the best scientific work on sewage that has ever been published. He believes in anaërobic-action as a preliminary treatment of sewage, and his experiments have shown the remarkable effect of such action on large masses of animal matter, as the bodies of dead animals, and the difference in the action when fresh sewage is not allowed to enter the tank.

I should like to say something, also, regarding the opinions of many English sewage engineers as to the causes of the failures of the septic tank as commonly used as a method of preparing sewage for contact beds and percolating beds, and why Leeds has abandoned septic tanks in favor of chemical precipitation, but this, like the other subjects to which I have referred, requires too much time to be entered upon this evening, and, feeling that I have already taxed your patience, I will finish as I began, by congratulating Mr. Clark on having made this

meeting one of the very interesting meetings of the Sanitary Section.

PROF. C.-E. A. WINSLOW. — I was greatly interested in what was said to-night about the operation of trickling filters and about the Essen septic tank and the other points brought out. It seems to me that an enormous deal is being gained in the recognition within the last few years of the fact that we have three practically distinct problems to deal with — the removal of solid matter, the oxidation of organic matter (or the rendering stable of organic matter, I should say), and the removal of bacteria. Sometimes all of these are necessary, and sometimes only one or two of them, but the means to be adopted are practically distinct. We have various effective means for rendering stable organic matter, of which, I think it seems clear, the trickling filter, is on the whole, the most promising. You can't get away from that side of the problem, which is essentially a biological problem. The people at Hampton are emphasizing equally the physical problem, — the removal of solids. And the other problem, the filter problem, has been emphasized strongly by experience at the Technology station. We have a new filter there now which has been running for about a year. Three years ago we started a trickling filter and ran it for about a year. For the first six or eight months it gave us poor results. Then the summer came, and with the warm weather the nitrites began to go up very sharply. Some nitrites had formed before that, but after the extreme excess of nitrites and with the advent of warm weather the nitrites fell off and the nitrates increased, and after that the filter did splendid work for a year and a quarter. We took this filter apart and built another, and the history of the second is almost exactly the history of the first. In the spring the filter did poor work. But in the warm weather the organisms that make nitrates got to work and now the nitrates are beginning to go up and the nitrites are stable. It seems to me there is a very distinct biological cycle. I hope we shall soon have an opportunity to start a filter at another season so that we shall be able to see whether that long, latent period before the organisms that make nitrates get to work is really necessary. At any rate, that problem of rendering the organic matter stable is very well in hand. And the problem of bacteria removal is pretty well in hand. I think it is generally recognized now that that can be accomplished efficiently and economically by the treatment with chloride of lime. I hope that one of the next victims to-night may be Mr. Whitman,

in order that we may hear something of what they are doing in this line in Baltimore. The problem of the removal of solids is surely the great puzzle of sewage work. It is, therefore, particularly interesting to hear of the attempts made to solve that problem, and particularly of one of the most promising means, the spread of this Hampton idea as shown in the Essen tanks. For all these things we owe a great debt to Mr. Clark and Dr. Kinnicutt for what they have told us.

Mr. Whitman. — Professor Winslow has just spoken of the disinfection of sewage and sewage effluents by means of chlorine, and in his remarks about the presence of one very familiar with this work, I presumed he referred to the pioneer in this line of work in America, Professor Phelps, of the Massachusetts Institute of Technology. During the past year we have, with the collaboration of Professor Phelps, carried out in Baltimore, at the Walbrook Sewage Testing Station, a series of experiments on the disinfection of sprinkling filter effluents with solutions of commercial bleaching powder. Our results have been extremely satisfactory, so satisfactory in fact that our final plans for the sewage disposal works at Baltimore will include a chlorine disinfection plant.

In order to give you a clearer understanding of our work in Baltimore on the disinfection of sewage effluents, I will first give a brief description of the sewage testing station which was established at the beginning of the active work of constructing the sewers and sewage disposal works soon after the present Sewerage Commission was organized.

At that time there was no sewer or system of sewers from which sewage could be taken for experimental work as was done at Columbus. There were a number of storm-water drains into which, when they were first constructed, no house sewage was allowed to drain, but which have been tapped more and more frequently by private drains and house connections, until a number of them carry large amounts of house sewage. None of these were located, however, in parts of the city where a large scale testing station could be located, and it was decided to build sewers in one of the suburbs, Walbrook, where a suitable location for the testing station could be built. This called for laying of about 13 000 ft. of sewer in connection with the testing plant.

The primary objects for which the testing station was constructed were to determine the depth of bed and the size of stone required to give the high degree of purification called for by the

local conditions in Baltimore at the main disposal works. The testing plant itself consisted of a settling tank, twelve sprinkling filters and twelve sedimentation basins through which the effluents from the sprinkling filters passed. A detailed description of the plant can be found in the *Engineering Record* of November 17, 1906. The twelve filters were constructed so that four were 6 ft. deep, four 9 ft. deep, and four 12 ft. deep. The four beds of each of these depths were constructed of different sizes of stone, making a bed of each depth constructed of the same size of stone. These four sizes of stone were $\frac{1}{2}$ to $1\frac{1}{2}$ in., 1 to 2 in., 2 to 4 in., and 4 to 6 in.

In addition to this testing plant a laboratory building was constructed and equipped for chemical and bacteriological analyses of the sewage and effluents. Operation was begun at the station on August 1, 1907, and the chlorine disinfection work started in November of the same year.

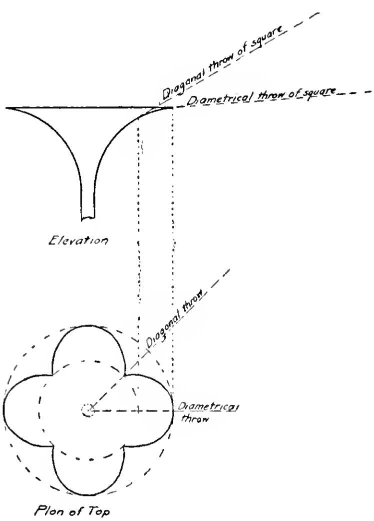
Our first experiments in the disinfection work were with the effluent from the filter 12 ft. deep, made up of the $\frac{1}{2}$ to $1\frac{1}{2}$ in. stone. This effluent, before disinfection, was practically always stable as shown by the methylene blue test, and contained an average of from 100 000 to 150 000 bacteria per cu. cm. In our experiments the quantity of available chlorine added to the effluent varied from less than 1 to about 4 parts per million. By the use of 3 parts per million the total number of bacteria in the effluent was reduced to from 1 000 to 10 000 per cu. cm., while the red colonies on litmus lactose agar were reduced 98%, and the reduction as shown by lactose bile and lactose broth were both over 90%.

In the spring of 1908, as our results seemed to indicate that 1 to 3 in. stone would be the best size for practical results, a change in the testing plant was made and four beds of this size stone, of depths of $4\frac{1}{2}$, 6, $7\frac{1}{2}$ and 9 ft. were constructed. The effluents from each of these beds are now being disinfected with chlorine, and we hope to determine by these studies if it will be possible to secure an effluent as well purified and as stable from a shallow bed treated with large quantities of chlorine as can be obtained from a deeper bed treated with a small quantity of chlorine. The results of these experiments have not as yet been carefully studied.

The objection raised by Dr. Clark to the unequal distribution over sprinkling filter surfaces by means of fixed nozzles is a serious one, but I hope we shall be able to overcome this in our Baltimore work where fixed sprinkling nozzles will be used.

Our nozzles will, I believe, be very different from any now in use in any disposal works. A nozzle similar to the one we propose to use was devised and used experimentally by Mr. William Gavin Taylor at Waterbury, Conn. A description of the nozzle was published by Mr. Taylor in the *Engineering News.*

This form of nozzle will give a spray the perimeter of which as it falls on the filter surface is approximately a square, the sides being fairly straight and the corners of the square somewhat rounded. The means by which this square spray is obtained is best explained by the accompanying sketch.



CONE FITTING IN NOZZLE ORIFICE

In our experiments we used wooden cones and cut them back to obtain the diagonal throw. We found that a large cone about 5 in. in diameter gave a much more satisfactory square under varying heads than could be obtained with the smaller cones.

Not only will the square spray form of nozzle be used, but the head on the nozzles will be varied in short periods of about five minutes, so that the maximum head will throw a spray covering a 15-ft. square while the minimum head will cover a 2-ft. square. This variation in head will be brought about by a butterfly valve revolving in the main distributor to each bed. The rate at which this valve revolves will be so regulated that every portion of the area between the 2 ft-square and the 15-ft. square will receive the same amount of sewage. That is to say, that in a 15-ft. square or in 225 sq. ft. the entire surface except 4 sq. ft. in the center, or over 98% of the surface, will receive sewage at a uniform rate.

Many interesting points in sewage disposal have presented themselves in the operation of the testing station and the design of the main disposal works, but before these are published we hope to be able to point to practical results.

Professor Kinnicutt. — How many parts of chlorine did you say?

Mr. Whitman. — From one to three parts per million of chlorine.

Mr. Robert Spurr Weston. — I would like to ask Mr. Clark if he has investigated the centrifugal machine as a method of sludge removal. I intended to go to see a plant in operation at Harburg, but unfortunately I could not. I was told that another plant was being built at Hanover, and I would like to ask Mr. Clark if he saw or heard anything about that?

Dr. Clark. — I got all the literature the centrifugal people have put out, and intended to visit the Harburg plant, but while I was at Hamburg I was told that it was not in operation at that time, so I didn't go to see it. I understand, however, it is in operation most of the time.

A Member. — Do you understand it is operating well?

Dr. Clark. — Yes, I think it is operating well. At the experiment station at Berlin I was told that it was giving very good results at a low cost considering the work done. But whether that statement was based upon experimental operation or operation at Harburg, I am unable to say.

Mr. Patten. — I should like to ask one question in regard to the large areas used for the disposal of sludge. Is it anticipated that those areas can be used in the immediate future, or at any time, for any other purpose?

Mr. Clark. — Yes, I think it is. Certainly at one place these areas are being used again. At York there is a large and handsome field that is simply a mass of buried sludge. The sod and soil are removed to the depth of one foot, then a layer of sludge 9 or 10 ft. deep is deposited and the soil and sod put back over it, making a field with a higher grade, but still a handsome field.

Mr. Patten. — And then go to a new field?

Mr. Clark. — Yes.

Mr. Patten. — Ever go back to the first field?

Mr. Clark. — No.

Professor Kinnicutt. — The same thing is being done at Leicester.

Mr. Fales. — When Mr. Clark spoke of this sludge at Birmingham on which neither grass nor weeds would grow, it occurred to me that that is what we thought when we pumped our chemically treated sewage sludge on to beds. They seemed at first to be a barren waste, but after a few years the grass began to grow and at the present time an enormous crop, or really three crops, are being cut from those old sludge beds. That is, the action

that has taken place on standing has been such as to induce this enormous growth of grass.

Mr. Clark. — I might say that in one or two other places, where there are both septic and chemical precipitation tanks, there was nothing growing on the sludge from chemical precipitation, after a year or more in place, whereas there was a rank and heavy growth of grass on septic sludge of equal age.

Mr. Fales. — We began to haul this sludge down on to the dump in 1899. Part of the swamp there has been filled in and the sludge has been standing for two or three years. We rented that land to parties living in the vicinity, and they farm it, trying various crops on that and the part of the dump which has been completed. A few years ago they tried potatoes and got a very good crop, but the potatoes were very scabby. But last year they tried another variety of potato and the results were certainly very surprising. I never saw larger or better potatoes growing anywhere than they produced from this sludge.

A Member. — As to size or flavor?

Mr. Fales. — As to size and quantity. I have no doubt the flavor was all right.

Mr. Weston. — We are indebted to Mr. Clark for a very valuable array of facts, and to Mr. Kinnicutt for his interesting discussion, and for his account of his own observations abroad. I think this question of removal of solid matter is one closely connected with the condition of the sewage before it gets to the disposal works. I think when comparing one sewage disposal plant with another we are apt to fail to take this into account. If the sewage is fresh and the suspended matter can readily be removed in the laboratory by simple filtration, it is in a condition to be removed by a comparatively short period of sedimentation in a settling tank. On the other hand, if the sewage has been comparatively a long time in the sewer and the suspended matter has become converted into colloidal or semi-soluble material by long-continued agitation, it doesn't seem that any system of sedimentation can be very efficient.

Regarding the distribution of sewage on trickling filters, I had the good fortune to visit the experimental plant at Leipsic last January. There the experts have been making experiments for three or four years on a small scale and later on quite a large scale, on beds 17 ft. wide by about 70 to 100 ft. long, and while the nozzle sprinkler has given a satisfactory distribution of sewage, they have obtained

equally good results with a distributor of the Barker-mill type, and even better results with the simple tile pipe distributor, such as was used in the old contact filter beds. These are simply tile laid with open joints at short intervals — I think 8½-ft. intervals — the pipe being taken up occasionally and cleaned when the joints become clogged. They also made some experiments with filling material for trickling filters and found that equally good results could be obtained with almost any kind of material, providing the size was uniform and suited to the sewage to be treated; that is, the broken stone, the furnace cinder and the copper smelter cinder all gave equally good results. But where the material was mixed, the coarse with the fine, a tight membrane formed on top of the filter, and caused the shutting off of air and the other bad effects mentioned by Mr. Clark. The effluent from this experimental filter in Leipsic was very good indeed. The sewage was simply settled in a grit chamber, with about six or seven hours' sedimentation, as I remember it, and the effluent from this passed on to trickling filters. It is hoped to obtain experience enough in this experimental plant to completely purify the whole sewage of Leipsic which is now discharged into the river after a short preliminary treatment.

Mr. Phelps. — Two points raised here to-night interested me particularly. The first is this matter of distribution. I agree with Mr. Clark fully that a great deal of our trouble comes from imperfect distribution. I have had that brought to mind in a striking way in making calculations of some of our sprinkler efficiencies. It seems to be a fact that with a good distributor — nozzle of the Columbus type, operating intermittently — giving what we call a good distribution, a considerable portion of the filter is being operated at rates four, five or more times the mean rate; that is, at rates of 10 000 000 or 12 000 000 gal. instead of 2 000 000 gal. Of course, the direct effect must be to overload those immediate areas with any suspended matter that may be contained in the sewage, and, eventually, to clog such areas. Then the sewage overflows into adjoining areas, clogging those, and so the building up of the clogged areas goes on until the whole surface becomes clogged. I don't think the solution is going to be along the lines of mechanical sprinklers unless we are prepared to adopt the suggestion of covered tanks, because those are bound to accumulate ice and go out of commission. I think the solution is to be sought along the lines Mr. Whitman has laid down, — a sprinkler that gives a square

instead of a circular spray, — so we shall not have to build expensive circular beds which will give us a distribution in a thin line in the perimeter instead of over an area, and then combining with that system an intermittency which will make that perimeter move in and out from the center to the periphery. Here is a striking illustration of the difference between good and poor distribution. We are experimenting with two filters running at the same rate, but with different distributors, one being an overhead distributor of rather poorer efficiency than the other, which is a Columbus distributor operating intermittently. The clogging under the poor distributor has been quite marked, though not enough to make us abandon the experiment, or to make it impractical with care and attention. Still it has necessitated digging over the surface twice, I think, within a year. On the other side the Columbus nozzle, giving us perhaps the best distribution we are able to get at this time with a circular spray, shows no signs of clogging.

The other point that interested me is that of the Hampton and Essen system of concentrated sludge treatment. It has seemed to me that in concentrated masses the organisms in the organic matter kill themselves out. It seems to be a matter of observation that sludge will not take care of itself so well in concentrated masses as when it is washed by the solution above it. We haven't any great amount of experimental data on this point, but I am strongly inclined to believe that the solution is going to be along the opposite line of keeping the sludge washed, so that the products of the reaction are carried off instead of being concentrated. In that way the action will be accelerated.

Mr. Harrison P. Eddy (*by letter*). — I have been very much interested in reading Mr. Clark's discussion of his observations upon sewage purification works abroad, and feel that the Society is very fortunate in having first hand the results of the studies of so competent an observer.

It is interesting to note that chemical precipitation — a method of sewage treatment which has been so severely and perhaps not wholly unjustly criticised in this country — is still in use in very many places and at plants of considerable magnitude. The ease of operation, the comparative simplicity of the processes involved and the freedom from the uncertainties attending most other methods of sewage treatment are appreciated by comparatively few engineers. The operation of this and other methods side by side quickly demonstrates this fact. When the floods descend upon snow-covered, partly frozen or seriously

clogged sand filters is the time when the works manager appreciates his opportunity to put in a few extra pounds of chemicals and allow the sewage to flow leisurely through the settling basin of his chemical precipitation plant. Unfortunately comparatively few of our cities are so situated that sewage treated in this way is sufficiently purified to be discharged into the available water courses.

The large number of municipalities which have found their earlier works inadequate and which are making radical changes in their methods demonstrates the wisdom of going slow in matters relating to sewage disposal. How often has a panacea for the ills of sewage discharge been heralded? Beginning many years ago with certain chemicals, as mixture of chemicals and inert substances, and coming down through the long line of discoveries to the septic tank, yet all have been found to be more or less wanting under some circumstances.

The wisdom with which our own State Board of Health has acted during the past twenty years is demonstrated no more clearly than in its conservative handling of the sewage disposal problems in many of the municipalities of this state. Often it has waited patiently, year after year, for some action to be taken, some progress to be made, but always exerting a steady, uniform pressure toward better conditions. This policy has, no doubt, prevented many mistakes and has permitted the board to maintain a highly respected position.

One cannot but be impressed with the magnitude of the sewage disposal works and of the expenditures made to solve these problems in England. Some of the individual plants have cost about as much, if not, indeed, more than all of our plants together.

We should not lose sight of the fact, and I believe it is a fact, that the conditions which have been encountered in Massachusetts are vastly more favorable than those which have surrounded our English contemporaries. It is hardly fair, for instance, to compare without many qualifying statements the results obtained at Manchester or Birmingham with those at Brockton and Framingham, — the one dependent upon works artificially constructed throughout, and dealing with immense volumes of sewage as well as of storm water; the other having at hand natural areas of sand of proper quality and dealing with mere driblets of sewage. A higher degree of purification has been obtained here, to be sure, but it is a question if the results obtained abroad have not required greater skill and greater ingenuity.

Mr. Clark emphasizes the fact which I have so often pointed out, that the suspended matter in the sewage causes the principal difficulties, and I belive this is equally true of all methods to-day employed for the purification of sewage.

One feature in which foreign disposal problems differ from many of those in America is that of the disposal of storm water. I had hoped Mr. Clark would deal with this question, which is most interesting and exceedingly important. In some cases in this country it has been believed to be necessary to build separate systems of sewers and drains to provide for a separation of the sewage and storm water now carried by a more or less complete combined system of sewers. Some progress has already been made along these lines, although the expense involved is enormous. In England, I understand that many of the disposal works provide for the treatment of a portion of the storm flow, and it would be very interesting to know what provisions are made for this treatment, what the results upon the rivers are, and if it is there believed that it will not eventually be necessary to separate storm water from sewage.

The very complete data relating to costs, materials and analyses given in Mr. Clark's paper make it a very valuable production for reference.

Mr. Clark. — I should like to say a word or two in conclusion. I am always glad to hear good reports from Dr. Kinnicutt of the Hampton tank because Dr. Travis who started this tank stated that it was based upon Lawrence work; in fact, he published a long article upon this fact, giving due credit to Lawrence; and Baker, in his book on "British Sewage Disposal," extracts several pages from this article.

As regards what Professor Phelps had to say of septic tanks, I also believe that the most favorable conditions under which sludge can be kept in a septic tank to insure destruction are as he states them, but I was not speaking so much about the destruction of sludge, as of the concentration of sludge. The Essen tank and, I think, also, the Hampton tank, although I am not particularly well acquainted with the latter, concentrate the sludge so that it contains only a comparatively small amount of water. That was the point I made in regard to this Essen tank. Enough sewage enters the sludge portion daily, I believe, to insure good septic action. In regard to the distribution of sewage upon sprinkler filters I only wish to suggest that, if perfect distribution can be obtained, a much smaller area will purify a unit volume of sewage satisfactorily than a larger area over

which the sewage is imperfectly distributed, as by the Birmingham and other types of nozzle working under a constant head; that is to say, if you can purify 4 000 000 gallons of sewage on an acre by perfect distribution even by distributors that would not work in cold snowy weather, it might be cheaper to cover that area than to construct an uncovered area twice as great for the purification of the same volume of sewage.

In regard to Professor Winslow's discussion on the formation of nitrates, I can only call his attention to the fact that this was very thoroughly discussed in the first report of the Lawrence Experiment Station written by Mr. Mills nearly twenty years ago, and that it has been shown many times at the Lawrence Experiment Station that filters started in cold weather will not nitrify until warm weather begins, while filters started in warm weather will begin to nitrify in a very few days. I can call Professor Winslow's attention to a table given by Fuller in the Lawrence Experiment Station report for 1894, page 475, where the data in regard to period of pre-nitrification of twenty-seven filters started between 1887 and 1894 inclusive are given, showing the period elapsing before nitrification began to vary from four to one hundred and fifty-five days, this being dependent upon the material of the filter, method of operation and time of year when started. I would also call his attention to the fact that a sprinkling filter started at the Experiment Station in May, 1899, and operated at a rate of 2 000 000 gal. per acre daily, contained over two parts of nitrates per 100 000 at the end of three weeks' operation.

In regard to what Professor Kinnicutt had to say of the slate contact beds of Dibdin, I wish to state again that I am only quoting from the recent report of the Royal Commission when I say that the results of these beds are anaërobic rather than aërobic just as was the result of a similar slate bed operated at Lawrence nearly nine years ago, and discussed in the Lawrence report for 1901. I should like to discuss the storm water question brought up by Mr. Eddy, but beyond getting the maximum and minimum flows at a number of areas and finding that at some areas the maximum flow is cared for and at others not, I gathered little data. The difference between maximum and minimum flows is of course slight compared with American figures, owing to the more frequent but much less heavy rainfalls.

I wish also to state, as I have before, that I do not agree in all respects with Dr. Kinnicutt's statement that bacterial perco-

lating filters had their origin in England. In this I am simply in accord with many of the best English investigators and experts along this line. There is no doubt that the contact filter of Dibdin is an English product. What, however, were the filters operated at Lawrence from 1892 on, constructed of stone, coarse clinker, coarse coke, etc., dosed many times a day and receiving sewage at the rate of from half a million to one million gallons per acre daily, but percolating filters? To be sure the sewage was not sprayed on, as on some of the municipal plants in England. The materials, rates and the results of these filters, however, were similar to the materials, rates and results of many of the so-called municipal sprinkling or percolating filters in England at the present time. I must also call attention to the fact that many of these sprinkling or percolating filters in England are operated in about the same way that these early percolating filters at Lawrence were operated — that is, intermittently; dosed once an hour for a short period and then a period of rest and again dosed. In order to show that English sewage experts do not all agree with Professor Kinnicutt in this respect, but with the statements that I have made here, I will call attention to a statement by that well-known expert, Scott-Moncrieff, in an article in the English periodical, *The Surveyor and Municipal and County Engineer*, of October 9, 1908, where he says, —

"The vogue of the contact bed is a case in point. It was introduced with no kind of scientific justification, and in this respect was quite different from the percolating filter, which obviously embodied the conditions required for the work of the nitrifying organisms in a much more satisfactory way, and had already been the subject of careful investigation in the United States."

[NOTE.— Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by February 1, 1909, for publication in a subsequent number of the JOURNAL.]

OBITUARY.

Irving Tupper Farnham.

Member Boston Society Civil Engineers.
Died September 19, 1908.

Irving Tupper Farnham, son of Charles and Julia (Tupper) Farnham, was born in Deposit, Delaware County, N. Y., August 21, 1869. While still quite young he worked at lumbering and upon a farm. Preparing at Deposit Academy, he entered the College of Civil Engineering, Cornell University, in 1888, and graduated in 1892, with the degree of Civil Engineer. The esteem in which he was held by his professors may be inferred from the fact that he held the position of librarian of the Civil Engineering Library during his last two years in college. After graduation he entered the Elmira Bridge Works in the draughting department, but, seeing better prospects in a position offered him on the force of the city engineer of Newton, the late Albert F. Noyes, left Elmira to take up that work in June, 1892. Here he obtained a practical training in an extended variety of municipal work, first as instrument-man on the drainage work of the so-called Cheese-Cake brook improvement; then on surveys for the assessors' block-system, and on the Hammond Pond drainage survey for the board of health. In 1894 he was put in charge of the field work connected with the surveys and construction of sections 1 and 2 of the Newton Boulevard, as division engineer, with a field office at Chestnut Hill. When this work was completed he was assigned to a similar position on the Washington Street widening and the abolition of grade crossings on the north side of the city. In 1898 he was in charge of the surveys of South Meadow brook improvement and the preliminary studies for abolition of grade crossings on the south side. After this work was plotted and reported on, the forces of the office were considerably reduced, and Mr. Farnham accepted a position as principal assistant engineer with the Massachusetts Highway Commission.

His services with the Highway Commission extended over a little more than a year, from February 6, 1899, to April 14, 1900. In this work his experience in the construction of Beacon Street and Washington Street boulevards in Newton proved of

much value to the commission, and the commission regretted greatly his departure.

In April, 1900, after the resignation of Mr. Henry D. Woods as city engineer of Newton, Mr. Farnham was appointed his successor and entered upon the much larger responsibilities of the oversight of all the engineering work of the city of Newton. This position he held until the time of his death.

Among the most important pieces of work carried out under his direction, the following may be particularly mentioned: In 1900 extensions of the main sewers along the banks of the Charles River towards Newton Upper Falls, and in 1901 a further extension under the bed of the Charles River at Echo Bridge in tunnel to Elliot Street. During this latter year also plans were made for a second section of the covered reservoir on Waban Hill and work upon its construction was begun, although it was not finished until the following year. In 1902 the sewers were further extended towards Newton Highlands and Chestnut Hill. These extensions, as well as some of the previous ones, involved tunnels under the Sudbury and Cochituate aqueducts of the Metropolitan water works, which had to be executed with the greatest care. An agreement having been reached with the Boston & Worcester Railway Company, that company began in 1902 the widening of some three miles of Boylston Street, on which the city of Newton put in the drains and catch-basins by day work, all under Mr. Farnham's direction. At this time he also designed and constructed a small auxiliary pumping plant for a sewer district at Newton Upper Falls which was below the level of the main sewer. In 1903 the work of abolition of grade crossings on the south side of the city was taken up with the Boston & Albany Railroad, and construction work was begun, all the changes of streets and drains being made by the city of Newton under Mr. Farnham's direction. The proper drainage of the depressed tracks required the lowering of long stretches of brooks and drains, besides some changes in the sewers. In 1906 Mr. Farnham designed and constructed a new concrete bridge over the Charles River at Newton Lower Falls, replacing the old red bridge to Weston.

In addition to the foregoing items, which are perhaps most worthy of detailed mention, there was the usual large amount of minor work which is always found in a city like Newton, and which received from Mr. Farnham the same conscientious and painstaking attention.

He was always a student and spent much time in investi-

gating all the details of plans and construction work which were in hand. He was ever pleasant with his associates and interested in their welfare. He took a great interest in the work of the Boston Society of Civil Engineers. He was a director of the society, clerk of the Sanitary Section, and chairman of the Committee on Run-Off of this section at the time of his death. He had taken an especial interest in the question of run-off from sewered areas and spent a great deal of time in its study.

Mr. Farnham was also a member of the American Society of Civil Engineers, the Massachusetts Highway Association and the New England Water Works Association. He had taken a particular interest in the affairs of the Highway Association and was its president in 1904. The following quotation from the resolutions passed by the Highway Association well expresses the esteem in which he was generally held:

"A man of character above reproach, an official of most devoted and thorough attention to every detail of his duties, a professional man whose grasp of difficult questions was sure to yield a convincing argument for or against the proposition involved, and whose courage never permitted him to lower the standard he had raised as a governing principle in his work, he had achieved an enviable position as a competent, safe and practical engineer, and there seemed no bar to greater success in his career.

"Too close application resulted in bodily affliction and breaking under the strain, and (we quote the language of his pastor at the funeral) 'sudden darkness came upon his mind, and in that moment of darkness, knowing nothing, he died.'

"His birth, school and college days, as a preparation for his future, and the time of his death are of your official records, and we add now a tribute to his memory, as of a man worthy to be followed in qualities which make for high purpose, purity of life, perseverance under difficulties and an abiding trust in the Eternal Wisdom, which made and controls the earthly existence and the destinies of men."

Mr. Farnham was a member of the Congregational Church in West Newton and much interested in its Sunday-school work. He was married on March 27, 1892, to Miss Jennie A. Carroll, who, with four children, survives him.

He was elected a member of this Society on March 17, 1897.

Charles W. Sherman,
Henry D. Woods,
Charles W. Ross,
Committee.

ASSOCIATION OF ENGINEERING SOCIETIES.

Organized 1881.

VOL. XLI. DECEMBER, 1908. No. 6.

ENGINE TERMINAL FACILITIES CONSTRUCTED BY THE WABASH RAILROAD COMPANY AT DECATUR, ILL.*

BY A. O. CUNNINGHAM, MEMBER OF THE ENGINEERS' CLUB OF ST. LOUIS.

[Read before the Club, May 20, 1908.]

THE Wabash Railroad Company has lately spent a large amount of money in improving engine terminal facilities at Decatur, Ill. This place is situated very nearly half way between St. Louis and Chicago, and is at the junction of the Springfield and Decatur divisions of the Wabash Railroad. The Decatur Division extends from St. Louis to Chicago, from Bement to Tilton, and from Bement to Altamont. and comprises 460 miles. All trains from St. Louis for points north and east pass through Decatur, so that this engine terminal is the most important on the system. There are approximately one hundred engines cared for here per day.

Previously to these improvements, engines were housed in an old and dilapidated building which had been in service over twenty-six years at the time when the improvements were commenced. The old engine house was too short for up-to-date engines, and the stalls consequently had been lengthened out to properly house the new engines. These extensions were generally made of wood. A new turntable was installed about six years ago, designed to fit the old foundations of the older turntable, and consequently its depth was not sufficient, with the result that there was usually too much deflection, requiring more power

* Illustrations of this paper are furnished by the courtesy of the *Railroad Age Gazette*.

to turn it than should have been necessary. It was operated by a 9 h. p. gasoline motor and did the work fairly satisfactorily.

Coal for the engines was obtained from a coal mine in the Decatur yard, which had a few chutes to accommodate the engines. A dilapidated machine shop, built on, piecemeal, to the old engine house, took care of the repairs to engines, and an old-fashioned cinder pit for taking care of the cinders from the locomotives completed the facilities at that time. Because of these poor facilities, together with the limited room and consequent congestion, the cost of handling engines was exceedingly great.

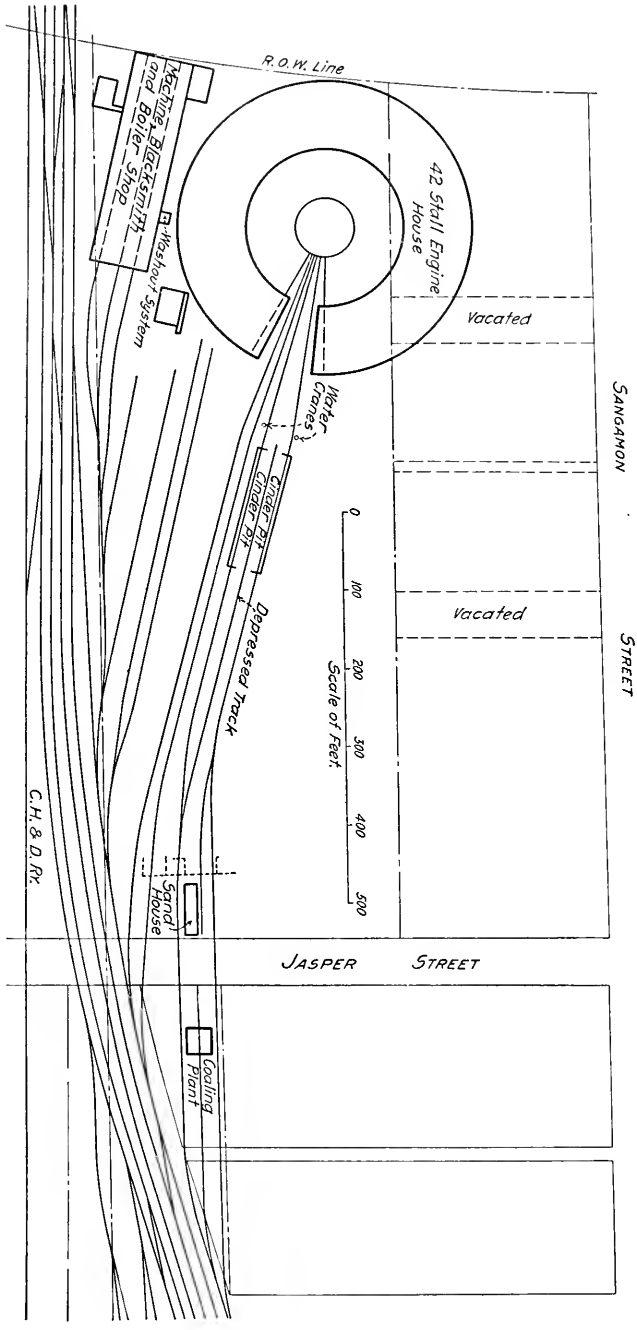
About two years ago improvements were started to rectify these defects and to lessen this cost. The first structure which it was necessary to build was the coaling chute, as the coal mine which formerly supplied the engines had practically given out. This coaling plant was constructed of timber on concrete foundations. It was designed with an elevated pocket that would hold 200 tons of coal, from which the engines could be coaled from ordinary movable aprons, and was constructed by the Fairbanks-Morse Company. Coal is brought to the chute in bottom-dump cars and is dumped into a concrete hopper beneath the track. From this hopper it is emptied under control of the operator by gravity into hoisting buckets through an orifice in each of the two side walls of the concrete hopper. There are two of these buckets, each with sufficient capacity for holding a ton of coal, and as one bucket is hoisted the other is lowered. The full bucket on reaching the top dumps automatically into the receiving bin. The whole plant is operated by an electric motor, controlled by one man, but two men in addition are necessary to empty the coal from the bottom-dump cars. It requires about two and one-half hours to fill the bin provided no engines are taking coal during that time. But since engines are continually being coaled, it is necessary to operate the plant about ten hours, the capacity of the bin being sufficient to take care of the coal required during the other fourteen hours. As the cost of handling coal through a coaling plant is not systematically computed, nor is there any standard method for keeping it, with the result that figures purporting to give it are useless, the following method is employed to determine this cost: The cost of labor, supervision, etc., for operating for a period of ten hours is $7. To this should be added depreciation charges, interest on the investment and cost of maintenance. The cost of the foundations and concrete receiving hopper was $1 225, and for the superstructure above foundation, $7 550, including

the motive power and machinery, making the total \$8 775. The interest charge on this investment at 5 per cent. would be \$438.75. The depreciation should vary according to the length of time the plant is in service, so nothing should be charged for this for the first five years, but thereafter, a charge of 5 per cent. per annum should be made. This means that the life of the plant is assumed to be twenty-five years. Maintenance charges will vary greatly and will increase as the plant grows older; 1 per cent. per annum should take care of this. Assuming these figures correct, then the cost of operating the plant will be \$3 432.50 per year. As there are, on an average, 333 tons of coal per day handled by the plant, the cost for handling coal will be slightly less than 2.9 cts. per ton.

It should be noted that no charge has been made for switch engine service for transferring coal cars from the storage track to the depressed hopper. Such a charge would be proper, but could not be made in this instance, because this transference of cars is accomplished by yard engines which are compelled to take water in close proximity to this coal chute, and do this work directly after having taken water. Since the storage track is adjoining the coal chute, it would be impossible to make a proper charge for the small amount of work done by the switch engines in performing this service.

Usually in connection with a coaling plant there is installed a sand house for receiving and drying sand for locomotives, but as the sand house used with the old facilities was in good repair, it was moved to a new location and used in conjunction with the new facilities. It consists of a long oblong building with a tower at one end. The sand is brought in cars and unloaded by hand into the building, at one end of which is a sand-drying device, which is nothing more than a cast-iron barrel-shaped stove around which is fastened a very fine funnel-shaped screen. The sand is placed between the stove and the screen and on drying falls through the latter, after which it is shoveled into a hopper and driven by compressed air into the tower of the building. It falls by gravity from this tower through pipes which may be connected with the locomotives.

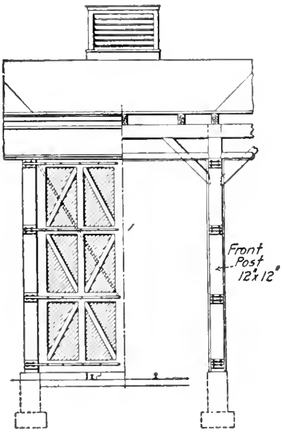
The next improvement was the construction of a new, up-to-date roundhouse with 42 stalls, new turntable and cinder pit, with all modern facilities for doing work cheaply. It might be claimed that the superstructure of this engine house is not up-to-date on account of its framework being of wood. However, there is but one other kind of material that could be used



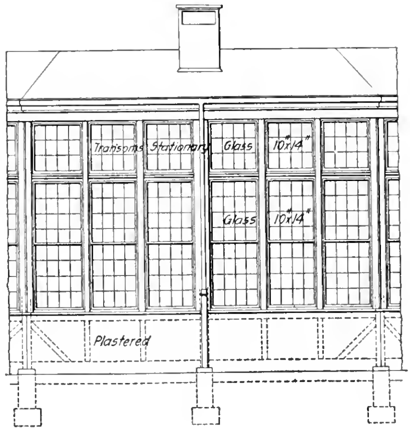
LOCATION OF 42-STALL ROUNDHOUSE.

in place of wood that would last any longer, and that is reinforced concrete. We all know that steel is soon rusted out where there is an abundance of smoke; therefore, steel unless properly protected should not be used in a roundhouse. Reinforced concrete construction is expensive, and, in the writer's opinion, not necessary because properly constructed engine houses with large timbers will last from twenty-five to thirty years, as smoke seems to preserve the timber. It is a waste of money to build such structures on Western railroads with the idea of making them everlasting, because these railroads are continually changing in their ownership and extending their lines, making it often advisable to change the location of their engine terminals and shops; and is it not also possible that railroads will be using electric motive power within a few years, requiring the reconstruction of engine shops and terminals? The only good argument for the use of reinforced concrete in buildings of this nature is the fact that it is fireproof; but there is so little danger of fire with a properly constructed engine house with heavy timbers that this argument need not be considered. In planning the construction of the new engine house, there were several things to be considered. First, it was necessary to do the work without interfering with the old facilities so that engines could be handled without loss of time. Further, there were three buildings in close proximity to the proposed site of the engine house which would work in with the arrangements of the new facilities. One was a boiler house about six years old, which could be used for heating purposes; another was a building of wooden construction, which could be turned into a machine shop, and the third was a two-story building which could be used advantageously for an office. It was finally found practical to so place the new engine house that these three old buildings could be utilized, and at the same time the new construction work could be carried on without interfering with the old facilities. As the Wabash had a year previously constructed large car shops in East Decatur, of which the operating power was electricity, and since there was ample current to spare from this plant, it was decided to use electricity to operate all the machinery and to provide light for the new terminal facilities.

The roundhouse is a complete circle, except for an opening sufficiently large to accommodate outbound and inbound tracks leading to the turntable. The house is of heavy mill construction, the timbers being of long leaf yellow pine. The construction is of the simplest kind, with posts between the stalls carrying the



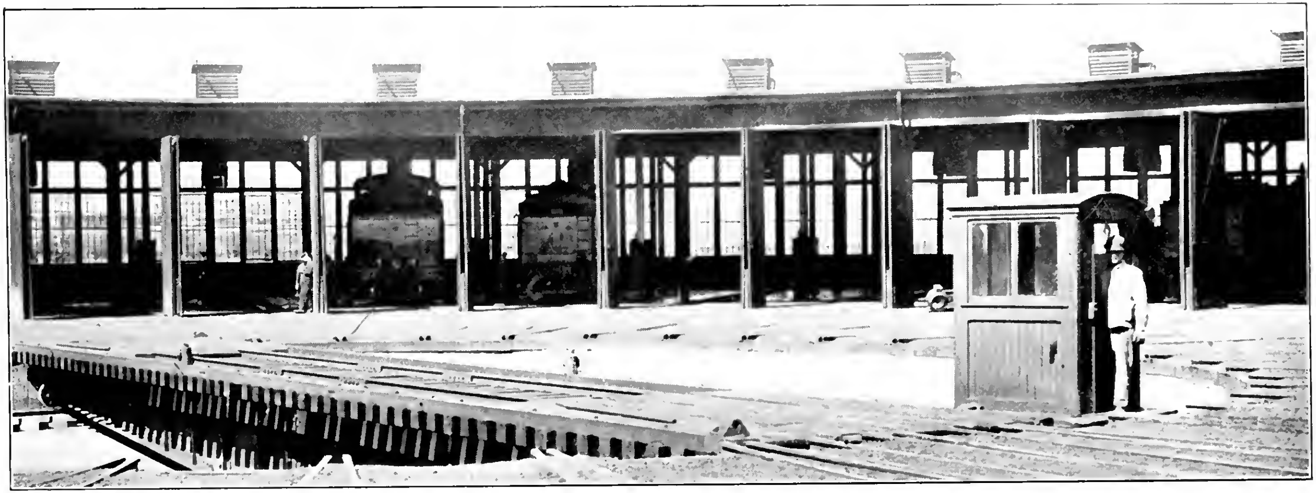
Front Elevation.



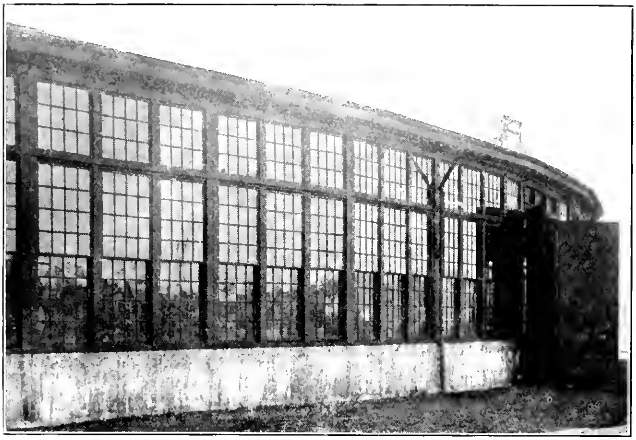
Rear Elevation.

roof so as to cheapen its cost. The roof beams supported by the posts run crosswise of the engine pits, and the joists, to which the roof sheathing is nailed, rest on the beams and run lengthwise of the pits. This enables the smoke from the engines entering or leaving the house to follow the joists and find exit at the peak of the roof, at which point there is provided a ventilator over each stall, each ventilator being accommodated with a pivoted shutter, which can be opened or closed by a simple mechanism worked from the floor.

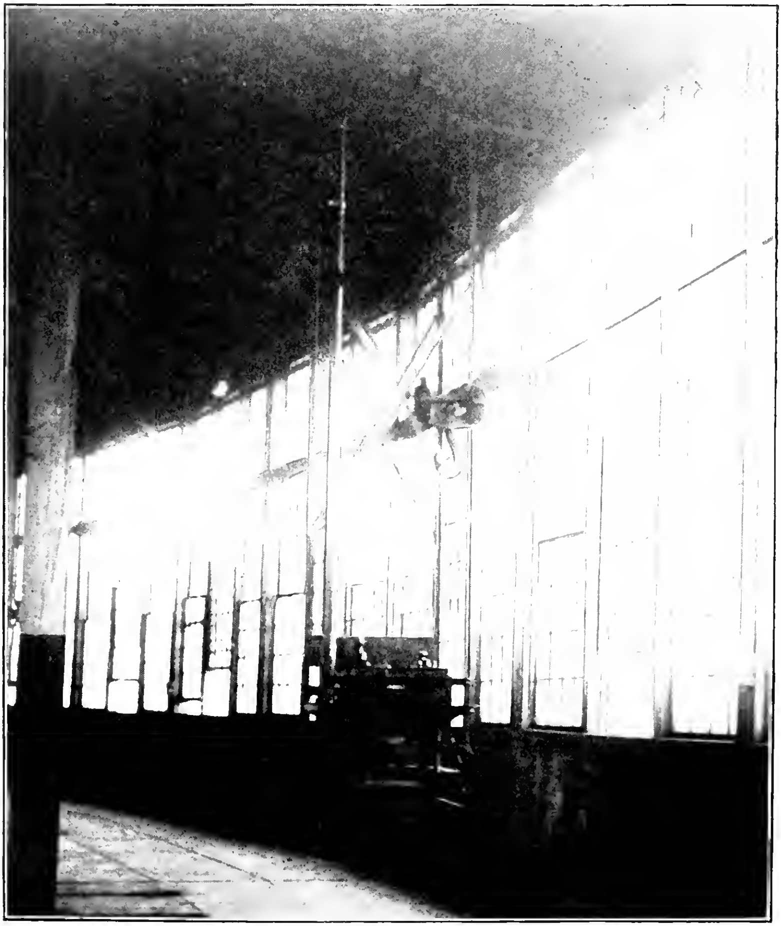
The walls of the building are constructed of wooden girts of the same width as the posts, and supported between them, to which is attached expanded metal, both on the inner surface and outer surface of the girts. The expanded metal on the outer surface is plastered on both sides with a mixture of Portland cement, lime and sand, and cocoanut fiber. The expanded metal on the inner surface is, of course, only coated on one side with the same kind of plaster. This construction provides a wall with a hollow space of air between, so that dampness cannot penetrate to the inner surface. The air space forms a good insulator to keep the building warm in winter and cool in summer. The plaster applied to these walls consists of one barrel of lime mixed with fifteen barrels of sand and four pounds of cocoanut fiber, the whole being mixed thoroughly with water and allowed to stand for at least two weeks so as to give the lime time enough to thoroughly slack. One part of Portland cement is then added to three parts of this mixture, with enough water added to make a plastic mortar. This is applied to the expanded metal and allowed to harden. This is called a scratch



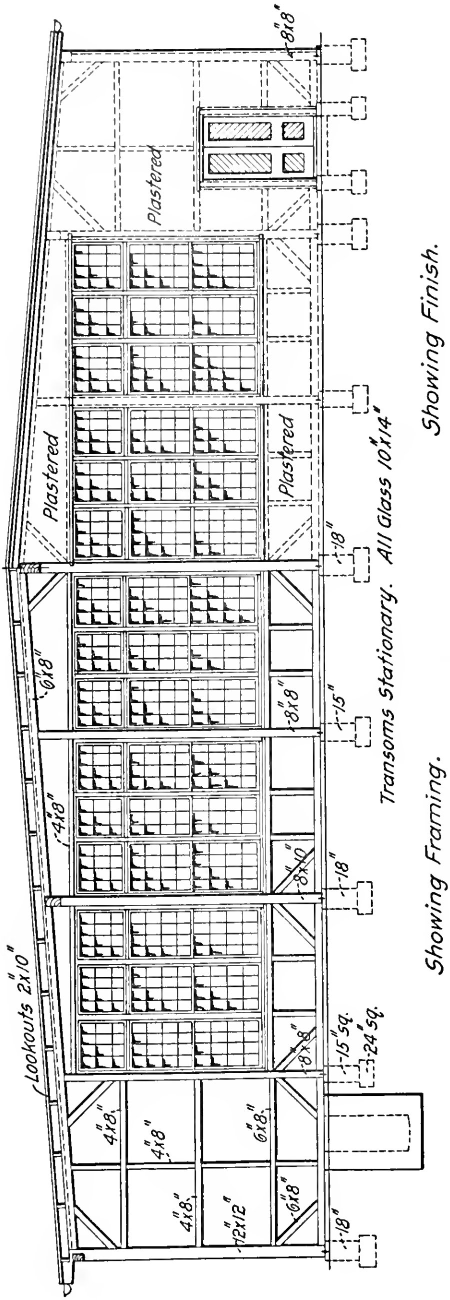
View of Inner Wall and Turntable; Wabash Roundhouse at Decatur, Ill.



Exterior, Showing Cement Base.



Telpher Hoist around the House. (See bottom p. 286.)



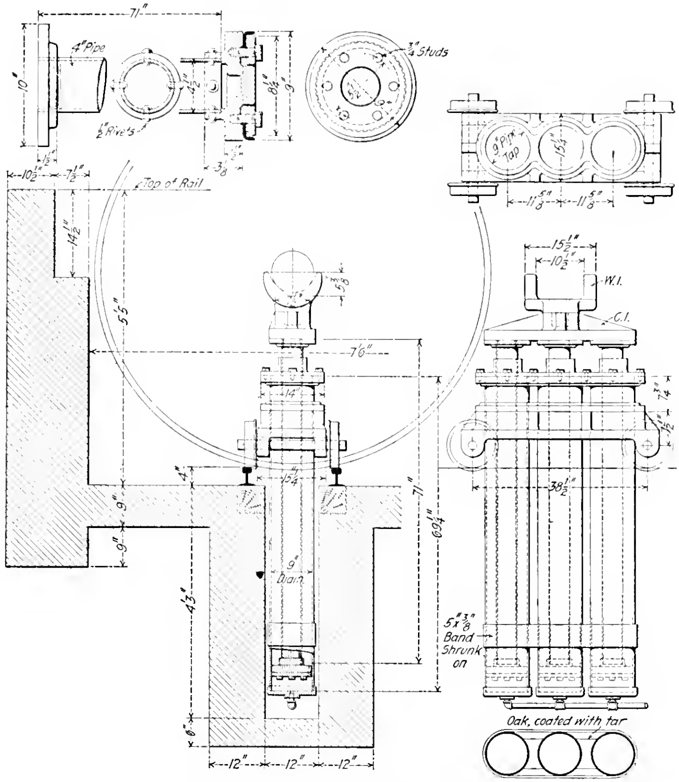
ELEVATION OF END WALLS OF ROUNDHOUSE.

coat. On this coat is plastered another layer of mortar, composed of three parts of sand to one part of cement. The plaster on the expanded metal on the outer surface of the house is 1½ in. thick, and that on the inner surface about ¾ in. thick. This hollow wall extends completely around the outside of the house, and from the ground to a height of 5 ft. The exterior face of the wall is painted with a waterproofing compound. On this wall is placed a continuous line of windows, which extend to the underside of the eaves of the building, thus providing plenty of light, which is very essential in such buildings. The cost of a wall of this description is slightly less than brick, but a saving is made because brickwork requires foundations to support it, while this construction requires only those necessary to support the posts. Also lintels are required over openings in brickwork, and none are required in this kind of a wall. A further advantage in this construction is that a continuous line of windows may be used, while with brickwork this is not possible, on account of the pilasters. The windows are made so that the two lower sashes are hung together with copper chains over pulleys; thus when one is raised the other is lowered; consequently they are counterbalanced without going to the expense of providing box frames with counterweights.

The doors in the front of the building are made of yellow pine, substantially built and with no glass in them. They are provided with convenient hand-latching devices, which lock them at the top and bottom when they are closed. To keep them in an open position, when necessary, there are provided pieces of old rail set in a vertical position in concrete and placed radially with the door posts on the outside of the building, to which are attached hooks which engage in eyes in the door to hold them securely so as to prevent damage being done to them from high winds and by locomotives entering and leaving the house. At certain intervals the large doors are provided with smaller ones, so that the house can be entered by men conveniently from different points.

The pits are of concrete and constructed so that in jacking up engines, in order to remove the parts, the jacks rest on projections built on the walls of the pit; otherwise, the floor of the house would suffer.

On account of the liability of concrete in proximity to the rails to break up, due probably to the oil which drips from the engines, it was decided to fasten treated timbers on the walls of the pits and to spike the rails to them. It was estimated



Pneumatic Jack for Driving Wheel Pits.

that the life of these timbers would be equal to that of the house, and, therefore, would be quite satisfactory.

Concrete foundations are provided to support the timbers on which the rails rest at the ends of the pits, and from the pits to the doors of the house, from which point to the turntable the rails are carried on ordinary track ties, under which cinder ballast is placed.

The pits open into a concrete duct, built entirely around the inner side of the front of the house. This duct serves the two purposes of draining the pits and carrying the heating mains, and is covered with checkered wrought-iron plates. In a convenient location of the house are constructed four driving wheel drop pits and two pony truck wheel pits. Over these pits the roof is carried by trusses, the posts being omitted so as to allow engine wheels to be moved between the pits and rolled out on tracks provided for them. One of these tracks connects directly with the machine shop.

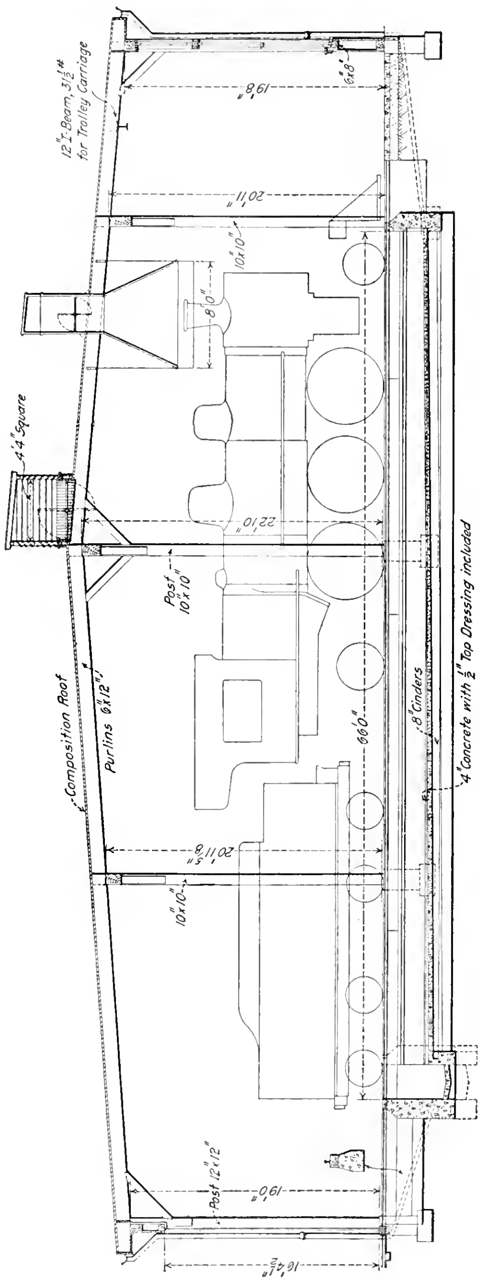
The floor of the roundhouse is of concrete, built similarly to a sidewalk, and placed on cinders. It is laid out in squares of about 3 ft. to the side, so if any square gets broken, as it is liable to be on account of the heavy pieces handled in a house of this description, it can be repaired at small cost.

The foundations carrying the posts are of concrete and are entirely separate from the floor, so if any settle, the floor will not be disturbed.

On the roof sheathing is laid a built-up roof of 5-ply tar and crushed limestone. The crushed limestone not only adds weight to hold the built-up roof in place, but, being white in color, helps to protect the tar from the rays of the sun. The cost of this roof covering in place was about the same as that of a prepared roofing.

One of the essential parts of an engine house is the smokejack to carry off the smoke from the engines standing in the house. So far, a satisfactory one has not been designed. Ordinarily, smokejacks are made of cast iron, which corrodes in a short time. Some of asbestos board have been tried, but they have not proved satisfactory. On this account it was decided to try a smokejack made of expanded metal attached to an iron frame plastered over with a mixture similar to that used on the walls of the building. The plaster covers up the ironwork entirely, and it is expected that a jack of this make will last a good deal longer than one of cast iron, with the advantage that it can be readily patched if it should become necessary. These jacks have now been in use for six months with no apparent damage to them. The only objection to them is their weight. If constructed with plaster 1¼ in. in thickness, they should weigh practically the same as cast iron. The style of jack best suited for a roundhouse is an inverted hopper leading to a chimney, the bottom opening of the hopper being about 3 ft. wide by 8 ft. long, to permit of the movement of engines two or three feet longitudinally from their proper central position, in order to get at their valves, etc. (See cut facing p. 291.)

In order to facilitate the handling of material from the roundhouse to the machine shop, a telpher hoist has been provided, running on an I-beam track, supported to the roof joists near the back of the house. This hoist is operated by electricity and will lift a load of two tons and carry it around the house at the rate of 300 ft. per minute, and in order to make it unnecessary to employ an operator continuously, a cage is provided, extending to within 3 ft. of the ground, so anybody can step into it from the floor and operate the machine. Some engine houses



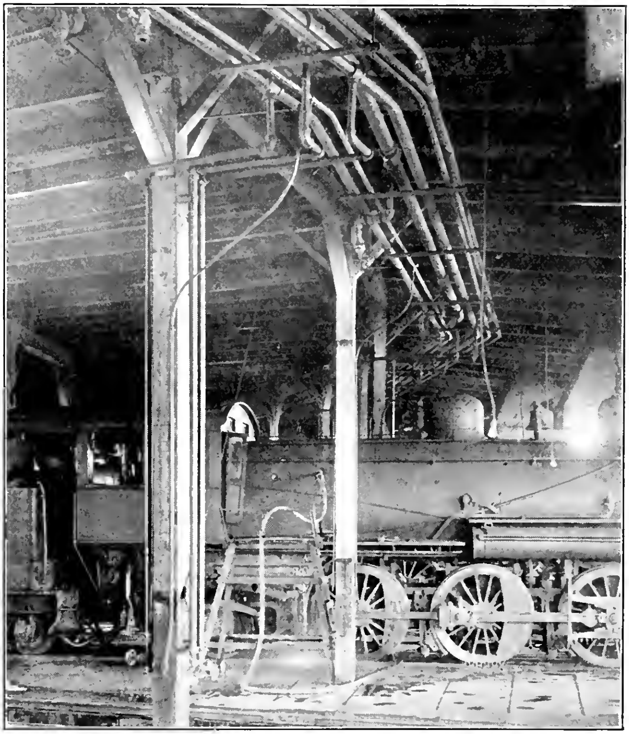
Cross-Section through Roundhouse.

have lately been constructed with a traveling crane with a capacity of 10 tons running around the outer circle of the house, and requiring an operator continuously, but as the maximum weight to be handled does not exceed two tons, the arrangement used in the Decatur house will do the work satisfactorily and at much less first cost, and with practically no operating expense.

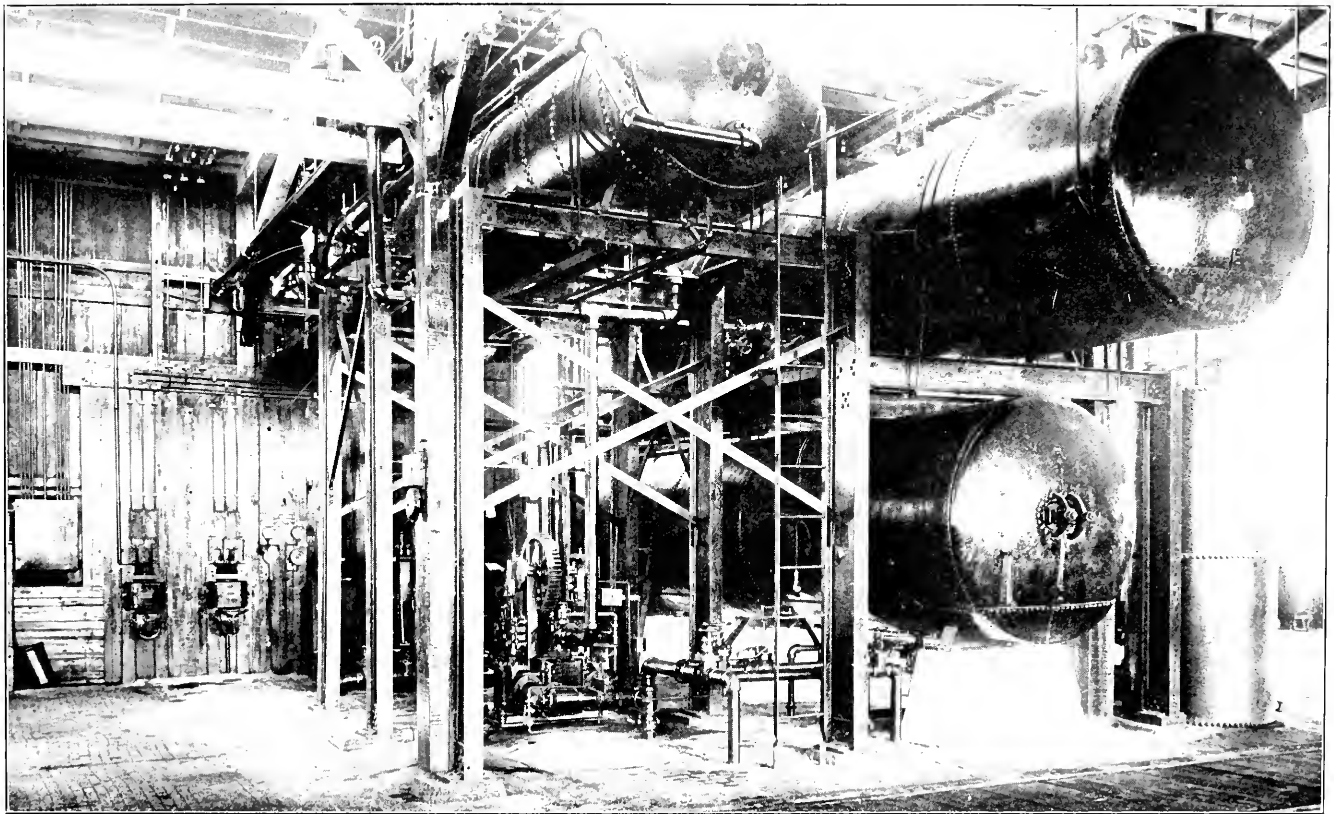
The water from the roof is carried off by downspouts and drained from the back of the house into the pits and into the duct from the front of the house. This duct empties into a catch-basin built on the outside of the house, which in turn is connected to the Decatur city sewer system by an 18-in. tile drain. The drop pits are drained by a 12-in. sewer pipe line connected with the 18-in. pipe line mentioned above.

The heating of the building is accomplished by a system of direct steam radiation, the steam being supplied from the boilers in the old boiler house. A 7-in. diameter main supply pipe with a pressure-reducing valve is connected to the boilers and runs underground to the duct inside the house, where it connects with a 5-in. diameter main branching both ways, and reducing to a 4-in. diameter pipe. This main connects with a system of four $1\frac{1}{2}$-in. pipe lines, which encircle the pits for radiating coils. These coils connect to a return system consisting of a $2\frac{1}{2}$-in. and increasing to a 3-in. diameter pipe, drained by gravity to a 6 by 4 by 6 in. Worthington pump and receiver, which returns the condensation from the coils to the boilers. At two intermediate places in the duct recesses are formed to allow for bends in the main and return pipes for expansion purposes. Globe valves are provided so that any pit can be cut out of service. The pipe used in the construction of the heating system was of wrought iron. This part of the work was installed by the Peters-Eichler Heating Company, of St. Louis, in a very satisfactory manner. As it is almost impossible to heat an engine house entirely, on account of the fact that the doors are very often open a considerable length of time, only sufficient heat is provided to properly thaw out engines as they come in from a trip during the winter. For this reason only 10 000 sq. ft. of radiation was provided. So far, this has been ample for all needs, and has kept the whole house reasonably warm.

One of the essential features of a roundhouse is the washout system, which should include a scheme for changing the water in the boilers of the engines when necessary. An elaborate plan for this purpose was decided upon, with the expectation that, with such a system in operation, the boiler repairs



Overhead Pipes for Hot Water Blow-Off, Wash-Out and Filling.



Plant for Washing and Filling Boilers with Hot Water; Wabash Terminal at Decatur.

would be considerably reduced. From results obtained so far a great saving is being accomplished, due to the large reduction in boiler repairs and to the diminished time required for washing out engines, thus greatly increasing their earning power; so the expense in installing this plant has been justified. The pipe lines in the house for this system are attached to the columns close to the roof near the middle of the house. They consist of four different lines: one for washing out the boilers, which extends over 15 stalls; one for refilling the boilers, extending entirely around the house; and two lines for blow-off purposes, one for connecting to the water leg of the engine, covering 15 stalls, and the other to connect to steam dome of the engines, extending completely around the house. The line that connects with the steam dome of the engines leads to a superheater, while the blow-off line from the water leg is connected with two tanks placed one above the other, the steam entering the upper tank, and the water and impurities falling by gravity to the lower tank. In the lower tank is placed a filter which filters out the impurities in order to utilize the purified water for refilling purposes. Pumps operated by electricity are connected with the refilling and washout lines. Cold water is admitted to the system of tanks when required from the Decatur city water supply. In connection with this system there is a temperature-controlling device, which is intended to mix the cold and hot waters to any desired temperature before they are circulated through the house. The heater and the different tanks, with the pumps and temperature controller, are situated in a part of the building which is utilized for the machine shop. With this system an engine can enter the house and have water in its boilers removed and fresh water of practically the same temperature returned to it, and be under steam and ready for the road within two hours' time. If it is necessary to clean out a boiler, the engine is brought on one of the 15 stalls provided for this purpose, the steam and water drawn off, and the boiler thoroughly washed with water of a high temperature. The temperature of the water used is usually about that of the boiler itself, so that the tubes and plates will not be cooled too quickly. There are, on an average, 18 engines per day blown off and refilled or washed out by this plant. The washout system was installed by the motive power department of the Wabash Railroad, the preliminary plans being furnished by Mr. Frederic A. Gale. Patent rights of this system are controlled by the National Boiler Washing

Company. The plant as finally constructed was not built in accordance with the original plans, but was somewhat modified.

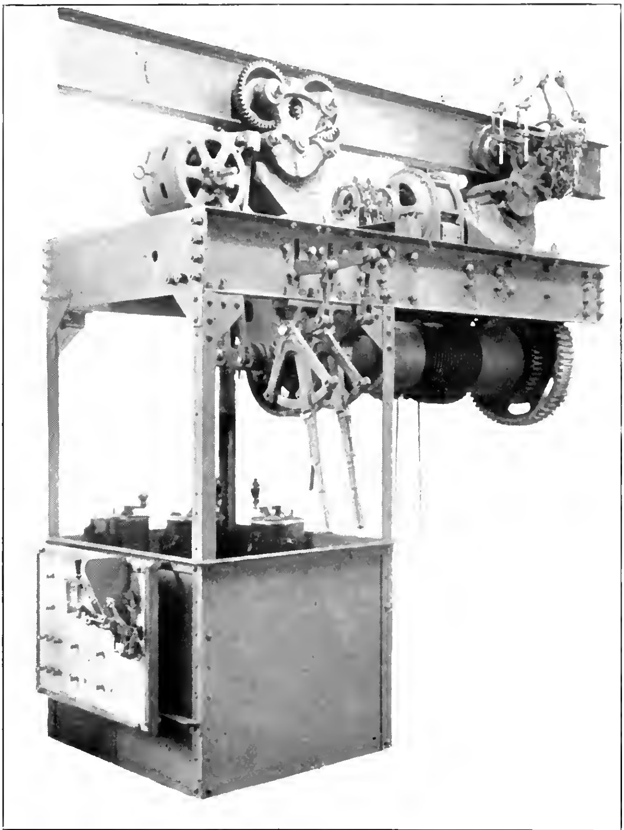
The turntable foundations are supported by piling and are of concrete. The center or pivot foundation is reinforced with rods just above the head of the piles. The circle rail is spiked to short ties laid without any fastenings on the circle wall. The pit is paved with concrete in a manner similar to that in the house and is drained by a 4-in. tile into the catch basin previously mentioned.

The turntable is of the deck type, 75 ft. long, with a live load capacity of 215 tons, and is turned by means of a tractor wheel running on the circle rail and operated by electricity. The steel work of the turntable was built by the American Bridge Company, and installed by employees of the Wabash Railroad Company.

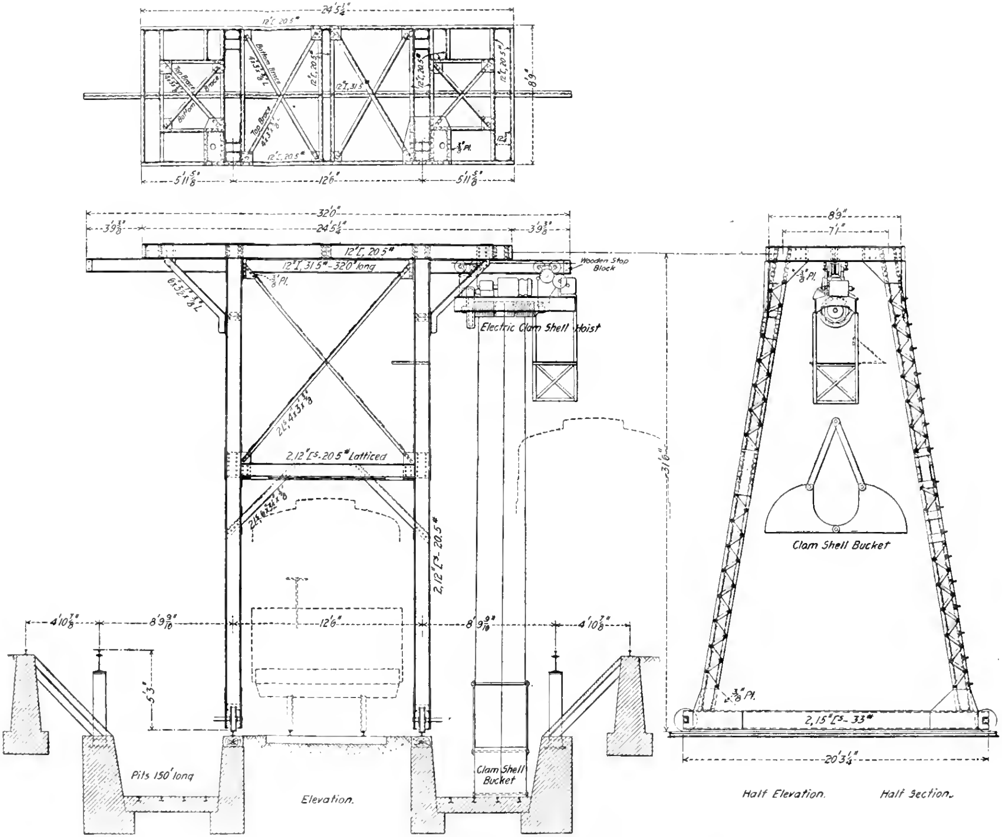
As the cost of labor for handling cinders had been very large formerly, amounting to $600 per month, it was decided to build an ash-handling system that would reduce this cost to a minimum. The structure was planned to have sufficient capacity to hold at least all the ashes deposited by the engines during twenty-four hours, and was provided with machinery with which to load the ashes economically. Concrete cinder pits were constructed in duplicate, 160 ft. in length, in order to permit three engines to be on each pit at a time. The cinders from the engines fall by gravity down an incline into a concrete pit filled with water. Cinder pits are usually hard to maintain on account of the hot cinders collecting in spots and destroying anything in close proximity to them. For this reason, the sloping sides of the pits on which the cinders drop are paved with brick. Columns supporting the track beams and rails are of cast iron of 1-in. metal filled with concrete.

In order to handle the cinders cheaply and quickly, a gantry crane is provided to run on rails between the duplicate pits, on which is hung a telpher hoist, capable of raising a 4-ton weight. This raises and lowers and operates a clam-shell bucket for picking up the cinders and depositing them in cars. A cage for the operator is attached to the telpher, so that he is directly over the bucket at all times. This gantry crane is operated by electricity and moves lengthwise of the pit, while the telpher hoist moves crosswise of the pit. This scheme has worked admirably, and while, as stated above, it cost $600 per month formerly for labor to load the cinders, with this device it practically costs nothing, for the reason that this work is done

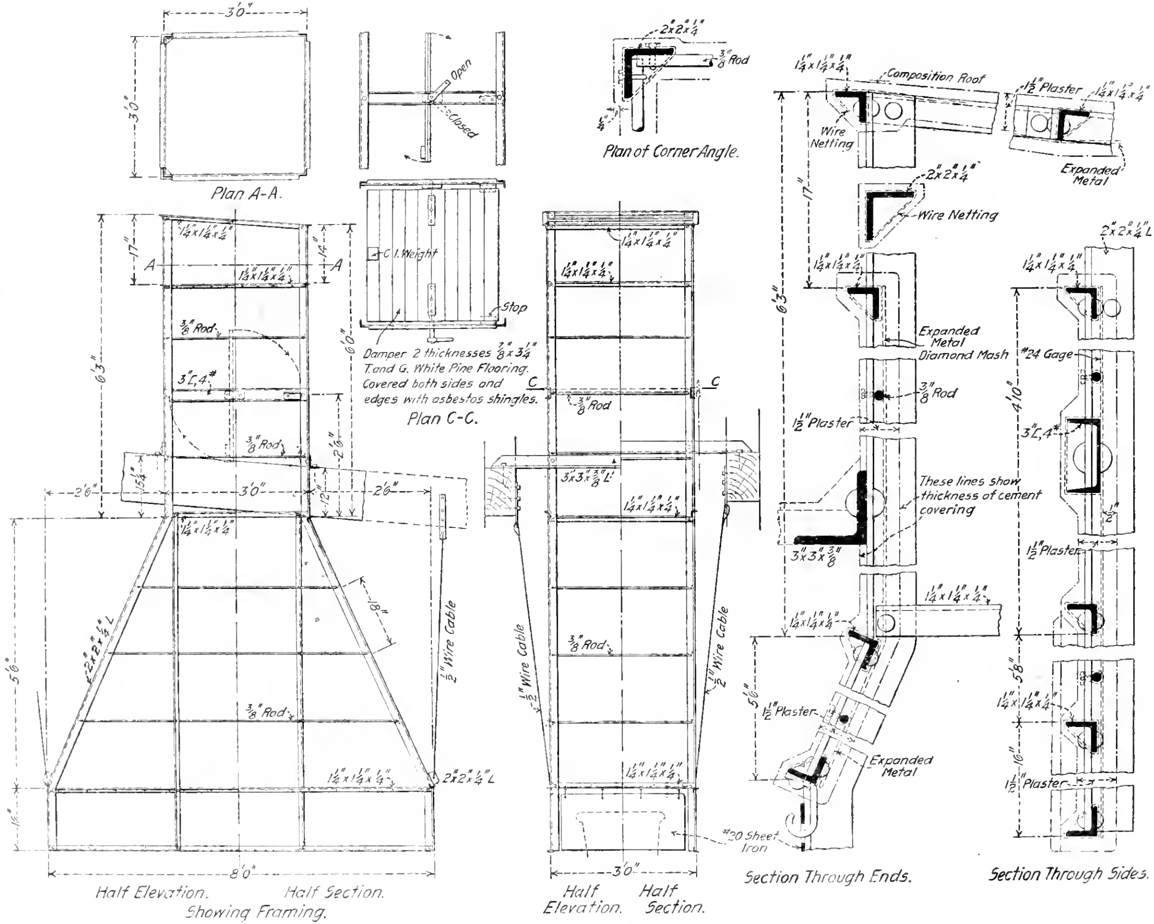
Ash Pit and Gantry Hoist.



Electric Hoist for Ash Handling Gantry.



Electric Gantry Crane for Handling Cinders; Wabash Terminal at Decatur.



Steel Smokejack for Wabash Roundhouse. (See p. 286.)

by any hostler who may be idle at the time. A certain number of hostlers have to be employed to take care of the engines during rush hours, so that any spare time they have is utilized in operating this machine. There are 70 yds. of cinders removed daily from the cinder pits.

Jas. Stewart & Company, of St. Louis, were the contractors for the house and cinder pits.

The steel work for the gantry crane was constructed by the Decatur Bridge and Iron Company.

The telpher hoist and machinery for the gantry crane, and the telpher hoist for the roundhouse, were constructed by the Case Manufacturing Company, of Columbus, Ohio.

The cost of the above improvements is given below in detail; but, as will be noticed, it does not include the value of the old buildings utilized nor the value of the old machinery and cost of labor for installing it in the machine shop.

Engine house and turntable foundations	$60 000	
Roofing	2 000	
Heating system with pump well, etc.	6 220	
Smoke jacks	2 100	
Door anchors	100	
Drainage and sewerage	1 950	
Wiring and lights	1 000	
Grading	600	
Engineering in field	1 000	
Track inside of engine house (value)	1 675	
Telpher hoist	1 000	
Washout system and motors	6 900	
		$84 545
Track between turntable and engine house and labor laying (value)		1 955
Turntable pit and foundation	$3 360	
Turntable	2 430	
Circle rail and track on turntable (value)	685	
Machinery for operating turntable	1 075	
		7 550
Cinder pit	$6 875	
Gantry crane	835	
Machinery for gantry crane	2 950	
Clam-shell bucket (value)	600	
		11 260
Coaling station		8 775
Sand house and machinery (value)		2 000
50 000-gal. water tank and fixtures (value)		1 100
Three water cranes with water pipes and fixtures, etc. (value)		1 000
		$118 185

NOTE. — Items with the word "value" written after them indicate that the material or structure had been formerly used with the old facilities. The amount given is the cost if new.

[NOTE.— Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by March 1, 1909, for publication in a subsequent number of the JOURNAL.]

THE USE OF ASPHALTUM.

By Harry Larkin, Member of the Technical Society of the Pacific Coast.

[Read before the Society, August 28, 1908.]

The paper relates to the various uses of a substance which has been at the service of mankind from the earliest history, in fact, before the date of authentic record. We find evidence of its use for cementing the bricks in building the great temples of the Sun-god and the Moon-god and in other stupendous structures that in ages long ago stood where Babylon with its architectural grandeur housed the rulers of a world, recorded in the most ancient of histories.

The Assyrians used asphaltum for waterproofing the immense irrigation canals built four thousand years ago, and their sources of supply, the fountains of Is, on a tributary of the Euphrates, still yield forth.

The Bible tells us that our forefather, Noah, used this material for rendering the Ark watertight, and that Moses' cradle in the bullrushes was bound together with " pitch."

With such a venerable history as this, it is a strange fact that an intelligent use of asphaltum to-day is an exception both in architecture and engineering. In most cases the advent on a job of a kettle accompanied by barrels of asphaltum, buckets, mops, felt, gravel, etc., etc., is looked upon with contempt—a disagreeable detail that it is hoped will soon disappear. The nature of the work prevents the mechanics looking like the " élite," but, nevertheless, it takes years of practice and experience to develop a thoroughly competent workman in the handling of asphaltum in any of its branches. To the passerby, the humble workman with sooty face and dirty clothing who tends the kettle is a common laborer. The truth of the matter is, however, that an incompetent kettleman may render the work performed very short-lived, whether it be roofing, paving or waterproofing, by overheating the asphaltum. *Here lies the keynote of all asphaltum work.* Nothing will kill the binding properties of asphaltum so quickly as overheating. In laying a felt and gravel roof, the topcoating will be shortlived, the gravel will not be properly imbedded and the roof will soon need recoat-

ing. In a paving job, if either the asphaltum or grit be overheated, the pavement will have no consistency and it will soon crack and go to pieces. In waterproofing work, the surface will be black and the contractor will probably get his money before any evidence of his imperfect work is discovered. On a roof, the greatest care and judgment must be used in laying felt to see that it is properly stretched, laid smoothly and that no wrinkles appear. The spreading of gravel is an art that few can learn; it takes judgment, quick action and a steady hand to get the gravel into the asphaltum before it chills and still leave the finished surface even. In the usual specification not enough stress is laid on the quality of the asphaltum used or on the workmanship. A certain number of plies of a specified weight of felt are called for, to be laid in compliance with the local building ordinances. This may comply with the law, but it does not guarantee a good roof. The same specification will probably call very particularly for a certain brand of cement in the item of the concrete, which is to be used in certain quantities, together with clean crushed rock and gravel. No roof should have less than 100 lb. of asphaltum to the square if a reasonably good job is expected. The asphaltum is the life of the roof, particularly in the topcoating. The gravel should be applied liberally, so that the asphaltum is completely buried and protected from the sun. If there be a little loose gravel on the roof, do not fear it; it will mean so many years more service, for that is what it is put there for, — to protect the asphaltum and felt underneath from oxidizing.

Then, again, asphaltum has been cursed by enthusiasts with ideas; well-meaning men who have done a little laboratory work have produced a sample and gone forth to organize a corporation to spring on the unsuspecting public a production thoroughly impractical in actual use. I have in mind such a corporation that was formed here some eighteen years ago for treating wood piles after a particular manner to prevent their being eaten by teredo and limnoria. These men sent out about a shipload of Val de Travers and Neufchatel asphalts (as good asphalts as have ever been on the market), but when it came to actual usage and wear their ideas proved a failure and the asphaltum lay for years in a warehouse on Battery Street. An honored ex-president of this Society, Mr. George Percy, was one of the few who recognized the superiority of this particular material, and I remember it well that he was ever faithful in specifying its use, to see to it that it was used in preference to all other kinds. In after years this asphaltum was reshipped to the Atlantic coast, the stock-

holders of the corporation having paid the bill for their experience.

In later years a certain contractor of San Francisco thought he could lay street pavements of redwood blocks dipped and coated with asphaltum. You probably remember his work on several of the wharves along the city front, and on Market Street in front of the Phelan Building. Wood block pavements had been laid in San Francisco twenty years before and were subjected to the hardest kind of wear in the steel warehouse of Dunham, Carrigan & Hayden Co., and the Haslett Warehouse at the time the contractor referred to put down his pavement on Market Street; this gentleman's knowledge of asphaltum was limited and as a result all of his pavements were a failure.

The old Boston Mastic Roofs, laid by Mr. Perine some forty years ago, were good serviceable roofs, but their success brought cheap imitations and the city was flooded with roofers who put down a ply of burlap, coated it with coal tar and gravel, collected their bill and flew. The result was that the mention of felt and gravel roofing to a prospective builder for twenty years after that was like a red rag to a bull. At the present time asphalt, felt and gravel roofing is almost universally used in this city, but I fear that some of the work done hurriedly after the recent disaster may have a tendency to shake some owners' faith in human honesty.

On the Pacific coast at present all of the asphaltum in use is derived from the refining of natural mineral oils, the deposits of natural rock asphalt having been exhausted. The process followed in its production is to place the natural oil in a still and take from it the volatile parts, such as benzine, distillate, lubricating oils, etc., the heavier carbons remaining, constituting the commercial asphaltum of to-day. The nature of the asphaltum obtained depends upon the density of the original oil, the care taken in not overheating the still and the length of time required in treating the oil. The hardness of the asphaltum depends upon the length of time it remains in the still — the longer it is treated the harder it gets. I consider that the only proper test of asphaltum is in the kettle, as an asphaltum taken from a high gravity oil may be treated in the still so as to come up to a specified number of points penetration according to the tests of our Board of Public Works and still be unfit for use either for making mastic, grouting basalt blocks or any purpose other than making paint or coating building papers.

Great improvement has been made in the production of

asphaltum in this manner during the past ten years; in fact to-day there are oil asphaltums in the market that very nearly approach the fine cementing qualities of the old rock asphalt. These are derived from low-gravity oils by refinery, where care is taken to produce a superior article. All asphaltums are black, but they are not all good. I am not from Missouri, but I must be shown more than a sample in a little tin can to convince me that the asphaltum I buy is suited to my purpose. There may be some means of telling the binding qualities of asphaltum in the laboratory, but experience teaches me that the most satisfactory means is to use a few barrels on the work and an experienced eye will know whether the material will do the work expected of it.

Asphaltum is a cement in a waxy form. It is nothing else. Its natural tendency is to contract, so that due allowance must be made where it is used either for roofing, paving, insulation or waterproofing. In roofing or waterproofing the object of using saturated felt is merely as a medium to hold the asphaltum together, to allow for expansions, contractions and settlings. In paving the asphaltum is simply a binder for the grit that takes the wear. The tendency to shrink will show itself in a pavement unless it is rolled out and worked by constant use. No better illustration can be shown than the asphalt mastic pavement originally laid in the quadrangle at the Stanford University by the old firm of Coil, Barton & Cowles, predecessors of the Alcatraz Asphalt Company. The pavement was laid as well and of as good material as money could buy, but a student's crossing of the "quad" occasionally was all the use it was put to. The pavement cracked and its surface looked like a map in a geographical atlas in a few years; it was eventually taken up entirely. If the "quad" had been open for driving, the pavement, in its greater part, would probably be good to-day, but lack of use wore it out. Like Portland cement, asphaltum in its pure state is of little use; it must be used in conjunction with felt, grit, gravel and a little common sense, to fill requirements, and it will, when properly and intelligently mixed, fill them well.

In building construction asphaltum is largely used in laying roofs. The methods followed are to lay from four to eight thicknesses of saturated felt over the roof surface, each ply being cemented to the preceding layer with a heavy coating of asphaltum. All felt is turned up at the firewalls and curbs at least 4 in. at the highest points of the roof, and not less than 12 in. high as the outlets are approached, in order to avoid overflows should the outlets become clogged. All such flashings should be

reinforced with an additional layer of felt (preferably flax felt) mopped solidly, running parallel to the wall, and counter-flashed with galvanized iron, or copper wedged, and cemented in place. The entire surface should then be floated with a heavy, flowing coat of asphaltum, in which, while hot, clean, dry, uniformly screened gravel should be imbedded sufficient in quantity to cover the surface thoroughly.

The character of the roof depends upon the style of the building. If a wooden sheathing is used as a foundation, I would advise that the first layer, next to the roof boards, be of unsaturated felt, serving as a dry sheet. There are two reasons for this: First, It is important in the life of the roof that it be free from the building so as to allow for shrinkages of lumber, settling, vibration, etc.; and second, an unsaturated dry sheet will prevent any excess of asphaltum dripping through the cracks, which dripping, however small the quantity, causes great annoyance in a loft building. In the case of concrete or tile construction, I would advise the use of saturated felt entirely, but I would lay the first sheet without mopping to the concrete or tile surface.

Some architects specify a metal standing flashing on felt roofs, but experience has taught me that this is a great mistake. In putting in such flashing it is necessary to nail through the metal and felt in order to hold it in place. Expansion and contraction soon loosen the nails, and if the flashing be in a position so that the water may flow on it, an opening will be found in the course of time to cause a leak. I never, under any circumstances, put a nail through a felt roof if it can be avoided, and if compelled to do so I make sure that it is well covered with felt. A reinforcement of flax felt, mopped on solidly, is more satisfactory in every way.

When an unusually fine job is wanted, a second coating of asphaltum and gravel is often put over the roof as heretofore specified; or, as in the case of light-well roofs, an improved appearance and a clean surface may be had by putting a cement top finish over the gravel roof; or tile may be set in concrete over it. But in any event, lay the roof first, complete with flashings and counterflashings, and then finish the surface to suit your taste.

Asphalt mastic has been used as a top finish over felt roofs, but this has not been altogether satisfactory on account of the tendency to contract, the mastic cracking in time and permitting water to lodge directly on the felt where this is laid without first

graveling it. Actinolite has given good service as a substitute for mastic where a smooth surface is wanted. Its cost and weight are much less than either tile, cement or asphalt mastic, and this material has the advantage of being adaptable to steeply pitched surfaces as well as flat ones. It is the only material other than tile that gives a thoroughly satisfactory smooth finish to a felt roof. This desire for a smooth surface is solely a matter of appearance, for accumulations of dust and dirt, that do so much harm to a metal roof, have a tendency to preserve an asphalt roof by protecting it from the sun's rays and oxidization. *The life of any roof is in its top finish.* If the roof be a plain felt and gravel roof, a liberal amount of asphaltum and gravel on top is of more importance than the number of plies of felt, or the quantity of asphaltum put between the sheets.

What is known as a felt-and-gravel roof should never be used on a surface of greater pitch than one sixth, or 4 in. to the foot. Where it is necessary to use an asphalt roof on a greater pitch, the gutters may be put in with plies of felt and asphaltum and the steeply pitched surface covered with some of the many ready roofings on the market. There is little choice between the different brands, for they all are laid with joints cemented and nailed to the sheathing. This nailing is what makes them so unsatisfactory; expansion and contraction of the body material in the course of a short time open holes alongside the nails and permit water to enter.

Asphaltum may be used to great advantage in other parts of a building. A recent fire on Market Street, opposite Sansome Street, brings to mind a fad of mine that appears to be in every way reasonable. At the time of the fire (which occurred in the upper story) newspaper reports stated that H. S. Crocker & Co. had a stock of \$25 000 of very perishable goods on the ground floor, the loss being \$23 000. Now, if in the construction of the building a waterproof course of two-ply felt and asphaltum had been put in the upper floors, the greater part of the damage to the stock below would have been prevented. Such waterproof course would have cost 3 cents per square foot, and besides making the floor watertight, it would have been the finest deadener of sound and barrier against rats that could have been put in.

In certain localities precautions must be taken to keep water out of basements. In these cases the treatment depends upon the character of the building and foundation. In heavy structures it is best to wait until the building is nearly completed, and when it has settled to its final resting place then pump out the

basement and over a thin foundation layer of concrete mop solidly three plies of good saturated felt, running the felt up the walls and piers a little higher than the natural level of the water, and cover this felt with from 8 to 12 in. of good cement and top-finish to serve as a floor. This cement must be built up around the piers and along the walls to support the waterproof course in place. On brick or concrete foundation walls a continuous course of asphaltum, applied to the outer side of the wall, will prevent entrance of ordinary dampness, but in cases where a great amount of water is present, I would recommend mopping on two plies of felt and filling in the earth at once as a support. The use of felt and asphaltum in waterproofing work is very general throughout the East, and some of the structures so treated are very extensive, such as the subways recently completed in New York. In letting contracts for such work, and in fact all asphaltum work, the integrity of the contractor is of greater importance than the cost, for it is seldom that a waterproofing job is so situated that it can be reached after the work is completed, and if there be a single defect, the full amount paid is loss.

The civil engineer often has use for asphaltum in lining reservoirs and flumes, and in waterproofing retaining walls and cisterns. The same simple rules of handling as already mentioned will apply. We all learn from noting failures, and I cannot help but mention here two particular instances of poor judgment or ignorance of the material that have come to my mind. When the water-works were built at Portland, Ore., some fifteen years ago, the three higher reservoirs were lined with concrete, and this lining was in turn coated with straight asphaltum. The coating was done during the winter season by unskilled workmen and, as a consequesence, was in patches and nowhere continuous. As the work was not satisfactory to Colonel Smith, the engineer, the entire surfaces were gone over with paving irons, and, in the course of time, the asphaltum was ironed together, but the life was burned out of it and an immense expense was incurred without accomplishing anything. If skilled workmen had been employed, the first application would have cost less and the job would have been acceptable.

The other case was a reservoir of the Contra Costa Water Company, on the outskirts of Berkeley. The reservoir leaked and a specification was prepared calling for the surface to be coated with asphaltum in which burlap was imbedded. This burlap was in turn given a heavy coating of asphaltum, probably

two coats. Where the mistake was made was in the burlap. Asphaltum will not penetrate anything while in its natural state. No force can be applied that will make it enter the pores of burlap, canvas, concrete, brick, stone or wood. As soon as it chills it sets, and in the case of the burlap, a simple surface coating was made through which the fibers of the burlap extended, to rot and draw moisture into the body material, to cause it to decay in turn. If a material like flax felt had been used, having for its foundation practically the same stock as burlap, but which is saturated with a preserving substance that harmonizes with asphaltum, the result would have been a satisfactory job instead of the failure, without question.

All of the roofing felts on the market are made of wool or flax, saturated with a preserving material that will harmonize with the asphaltum. The felts simply constitute a medium for holding the asphaltum in place, as before stated. The saturated wool roofing felts are compact, and although they absorb little of the asphaltum used in laying them, they hold it in repeated layers to constitute the body material of the roof or other structure to which they are applied. The flax felt is porous and of strong texture and absorbs the asphaltum, holding it within its fibers. An unsaturated burlap or canvas cannot be made to hold the asphaltum unless it be first run through a bath of flux, liquid asphalt or tar.

Herein lies a field for an energetic manufacturer: to produce a mixture of asphaltum and some material of the same specific gravity of the character of mica or asbestos, or something indestructible through decay, but which has a fiber to it that will hold the asphaltum together, or, in other words, that the asphaltum will hold together. Such a compound would be invaluable for coating reservoirs, pipe conduit, insulation, etc., if it be of a consistency easily handled. A refinery in Bakersfield is placing on the market a combination which it calls mastic, consisting of oil. asphaltum and lime from the beet sugar refineries. The lime tends to toughen the asphaltum in the same manner as sand, but it lacks the fiber to bind it together. The firm has the idea, but as yet it has only succeeded in adulterating the asphaltum without any material gain.

Asphaltum has been used in various characters of paving with varied success. The bituminous rock which has been so generally used in California is a natural mixture of sand and asphaltum found in large deposits along the coast. For sidewalks or streets having moderate wear it makes a very satisfactory

and cheap surface covering. Wherein it is weak is in the loam and vegetable matter in the mixture, and in the sand itself not being sharp; besides, the method of disintegration with steam leaves the finished pavement porous so that when the cold and damp weather comes on it cuts out into ruts. The character of "poultice pavement" more recently used in San Francisco has been a mechanical mixture of crushed rock for a binder, with a similar mixture of asphaltum and sand for the wearing surface. Provided the sand be clean and sharp, these pavements will give far better service than bituminous rock. Both the asphalt mastic and bituminous rock pavements cost little to keep in repair and have the advantage of being the most sanitary covering that can be placed on a public street. For streets having heavy traffic or even a slight grade, there is nothing better for wearing surface than basalt blocks grouted with clean warm gravel and asphaltum. It was a great blessing to San Francisco that Third Street, from the freight depots to the business centers, was so paved at the time of our recent disaster, for it gave us a passable thoroughfare over which to truck our supplies for building and stocking up the mercantile community again. After thousands of tons of all kinds of material have been hauled over it, the street is in good condition to-day, barring a few minor faults caused by excavations necessary for connecting new buildings. I doubt whether the city has spent a cent on this thoroughfare from Townsend Street to Mission Street since this pavement was laid some five years ago.

Pavements consisting of wooden blocks laid on vertical grain, dipped and grouted with asphaltum and warm gravel, make an excellent wearing surface for driveways inside of buildings. They are comparatively noiseless and furnish a good foothold for horses. In warehouses nothing will give better satisfaction. I consider fir blocks, cut at least 4 in. long, out of stuff not over 4 by 8, will make the best pavement when the blocks are laid to break joints and are well grouted with gravel and asphaltum. In case of very heavy teaming, blocks 6 in. deep would be better, but I would not recommend larger sizes than 4 by 8, as before mentioned. Creosoting the blocks does more harm than good. If the blocks are well dipped and grouted, they will never fail through decay. In this climate a wooden block pavement will never give satisfactory service out of doors. It is for this reason that I confine my recommendation of it to the use in warehouses and driveways under cover.

The foundation is all important whatever the character

of the pavement. Concrete has no superior. Our practice of ripping up a pavement for sewer, water and gas connections, and for laying conduits, has been the cause of numerous faults in our streets, but if the repairs were conscientiously made, the patching would never be evident whatever be the character of pavement. That is one peculiarity of asphaltum — it will heal over an injury in a roof or pavement, when the patch is properly applied, at a small cost, and in the end will be better than new. It has always been a source of pride and satisfaction to the asphaltum man to know that when the good metal, slate or tile roofs leak, or the concrete or brick walls sweat, he will be sought in the end to apply his asphaltum in some form or another to remedy the defect. The use of a few dollars' worth of asphaltum in building the foundation walls and basement floors in localities like the Western Addition, north of Washington Street, or over the entire area of Berkeley, would save our clients endless expense after the residence is occupied. The two localities are peculiarly subject to underground dampness, and there is hardly a residence in either locality that is not troubled in winter. This is a hard matter to correct after the building is up, but an inexpensive one to prevent in first construction. Tile roofs please the artistic eye and appeal to our loyalty to peculiarly Californian mission architecture; but a course of felt and asphaltum is advisable under the tile, to keep the rain out in rainy weather when the advantages of the roof are most needed. Our changing from an iron to a steel age has rendered metal roofs of short service; the steel oxidizes so rapidly that it is only a question of a short time when the owner will send for the asphalt man to put a covering over his head that will let him rest securely and keep him dry.

The statements I have made favoring the use of asphaltum are with the presumption that intelligence be used in its application. Asphaltum is most excellent for some uses, but like wood, steel, stone or brick, it has its field and cannot be successfully used without judgment.

[NOTE. Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by March 1, 1909, for publication in a subsequent number of the JOURNAL.]

DISCUSSION OF PAPER BY C. E. GRUNSKY, "THE WATER SUPPLY OF SAN FRANCISCO, CAL."

(Vol. XLI, Page 73, September, 1908.)

F. P. Stearns (*by letter*). — Two reasons have induced the writer to discuss this paper. First, the serious criticism that for other than engineering reasons he has expressed views while acting in a professional capacity in San Francisco which differ from views which he has expressed while acting in a similar capacity in Los Angeles; and second, because of his interest in the engineering questions involved in the water supply of San Francisco.

The author of the paper objects strongly to the view of the writer that the water diverted from the Tuolumne River should be conveyed in a covered conduit instead of an open canal along a steep hillside, and he quotes from the testimony of the writer in 1905 relating to the open canal section of the Tuolumne project as follows:

"In an unlined open canal on a steep hillside, as in this case, water would deteriorate in quality both by its exposure to the sun in the shallow canal and by opportunity afforded for the pollution of the water; some would be lost by filtration, and such a canal would be more liable to accidents and interruption than a tunnel. It would seem to me advisable, in view of the very great length and cost of the work, that this portion should be built wholly in tunnel, fully lined, so that the works would be less liable to interruption and to the liability to pollution and deterioration of the water which I have spoken of."

He then quotes from the report to the city of Los Angeles a paragraph which, to the casual reader, might sustain his contention that different views were expressed in the two instances without an adequate engineering reason.

In the testimony quoted there are four principal objections to the plan — two relating to the efficiency of the plan for an unlined open canal on a steep hillside: *First*, that some water would be lost by filtration; *second*, that such a canal would be more liable to accidents and interruption than a tunnel, which then seemed the most advisable way of constructing a covered channel on such a steep hillside; and the *third* and *fourth*, relating to the quality of the water, that it would deteriorate by its exposure to the sun in the shallow canal and that there would be an opportunity afforded for the pollution of the water.

The writer still holds these views, and held them at the time he joined in the report to the city of Los Angeles, and that report is not in any way inconsistent with the views expressed in the testimony above quoted.

In regard to the loss of water: The only portion of the Los Angeles aqueduct which is to be left unlined is, as stated in the report, "for the first twenty miles through the Owens valley" where "the canal will be sufficiently below the normal water plane in clayey soil of close texture to require no lining." Everywhere except in these wet, flat lands the canal is to be lined with masonry. It is also to be noted that this portion of the Los Angeles aqueduct is a part of a feeder to the main storage reservoir and is a large canal having a capacity for conveying 700 cubic feet of water per second.

On steep side hills where there would not only be the loss of water above referred to, but danger of interruption and accident, the Los Angeles canal is not only to be lined, but also covered. This is shown by a quotation from the Los Angeles report relating to a section along the mountain side where the conditions are much like those along the steep side hill where the author of the paper proposes the unlined open canal:

"From Little Lake to Indian Wells, a distance by the conduit line of 24.5 miles, is a section of more difficulties than the ordinary, as the line must be supported on the mountain sides at an elevation of 200 to 500 feet above the valley, along which the highway follows at the base of the Sierra. Here a succession of tunnels, siphon pipes and bench conduit, excavated much of the way in solid rock, and covered from the outset with reinforced concrete, are required."

The question as to whether or not an open canal should be used on the portions of the Los Angeles aqueduct to which such construction is adapted involves entirely different considerations from the use of an unlined open canal as a part of the Tuolumne project, as originally recommended by the author of the paper. In his plan as then laid down, and as reiterated in the paper under discussion, he lays great stress upon the quality of the water, evidently having in mind the quality of the water as it flows in the mountain streams; but the quality of the water supplied to a municipality may be greatly changed in character by storage in reservoirs and by exposure in a shallow, open canal. It is not a part of the San Francisco plan to purify the water by filtration through sand, but to deliver it substantially as it comes from the pipes, with only a few days' storage in reservoirs en route and in the city.

In the Los Angeles supply, on the other hand, although the water comes from the Sierra Nevada Mountains with a purity probably closely equivalent to that from the upper reaches of the Tuolumne River, it is stated in the portion of the report which the author has quoted in his paper that it was recognized that when it reached the Owens River it was somewhat changed in character, so that it had a slight turbidity and stain. Neither this condition nor the fact that there is a small population in the Owens Valley, nor the further fact that the open channel does not furnish a complete protection against the deterioration and pollution of the water even in a desert region where there is practically no rain and no population, is of great importance in view of the additional fact that the water after leaving the Owens River will pass through a storage reservoir of fully two thirds the capacity of the proposed Hetch Hetchy Reservoir on the Tuolumne River, 200 miles from San Francisco, then be stored again in great reservoirs in the San Fernando Valley near Los Angeles, and then be thoroughly filtered, probably through the natural gravel-bed filters above the heads of the existing aqueducts, before it would reach the consumers in the city of Los Angeles.

It is a matter upon which there is a general agreement among sanitary engineers that even a somewhat polluted water can be made safe for drinking either by long storage or by adequate filtration, and with the double safeguard of very ample storage and adequate filtration, the water delivered to the city of Los Angeles should be more wholesome and palatable than that taken directly from a mountain stream.

Conversely, the most dangerous water supply is one taken from polluted streams without storage or filtration. Practically all if not all of the epidemics of typhoid fever which have been definitely traced to water supply have been of water either taken directly from flowing streams or which have been held but a short time in storage reservoirs before being delivered to the consumer. That sparsity of population is not a complete safeguard is shown by the epidemic at Plymouth, Penn., where the contamination of a stream resulting in an epidemic of typhoid fever was traced to a single farmhouse.

The plan under consideration for the water supply of San Francisco provides for taking water into an open canal from the Tuolumne River, 16 miles below the proposed Hetch Hetchy Reservoir, and about the same distance below Lake Eleanor on Eleanor Creek. In addition to the watershed tributary to the

portions of these two streams below the reservoirs, which will be delivered directly into the canal without storage, there is also an important stream known as Cherry Creek, the head waters of which are 37 miles, measured along the stream, above the point of diversion. During all seasons, therefore, when the streams are contributing water, a considerable proportion of the water diverted to San Francisco will be that taken without storage directly from a stream, and containing the suspended matter which is always found to a greater or less extent in the water of streams.

The open, unlined canal into which the water of the river would be diverted has a length of about 28 miles, and the greater part of it is located at an elevation of about 1 900 feet above the sea, in a territory in which there is a small population and where, according to statements made to the writer, the country is used for grazing. The rainfall at this elevation is about 33 inches per year, and most of this is concentrated in the half of the year known as the rainy season; during the other half of the year the sun shines almost continuously.

The proposed depth of water in the open canal is said to be 5 feet, and this presumably is the depth corresponding to a capacity of 100 000 000 gallons per day, as that figure is mentioned in the official report on a supply from the Tuolumne River, made by the author in 1901. The present consumption of water in San Francisco is about one third of this quantity, and in the earlier years the depth of water would be much smaller, probably not more than 2 or 3 feet.

The writer has observed many irrigation canals in Southern California, and even where lined with concrete there is a prolific growth of vegetation attached to the sides, and he sees no reason to doubt that vegetation would grow and decay in the unlined canal under consideration. In addition to this, he does not believe that it is feasible to intercept all of the rain water falling on the steep hillside above the canal at all times by a system of small ditches. Under these circumstances it seems inevitable that the water would deteriorate in quality in passing through such a canal.

The author of the paper, notwithstanding his claims as to the high degree of purity of the water from the Tuolumne River, evidently has in mind that as delivered in San Francisco it would not be above suspicion, because, after stating in his paper the various small reservoirs through which it would flow on its way to the city, he suggests that it "can be made to flow through the

proposed Belmont Reservoir, whose capacity is estimated at 3 000 000 000 gallons, although this would involve some additional pumping."

As the flowline of the Belmont Reservoir would be about 160 feet below the hydraulic grade line of the pipes leading to the city, all of the water discharged into this reservoir would require pumping, and, in order to use the pipes leading to the city to their full capacity, pumping against a head of about 160 feet would be required.

It is obvious that to carry out this suggestion for producing a more wholesome water would involve a very large annual cost for pumping.

Another criticism made by the author of the testimony of the experts in the San Francisco case is that they have stated that the water of the Tuolumne River would be unfavorably affected by storage in the Hetch Hetchy Reservoir, which, he says, is located in the mountains at an altitude of 3 600 feet.

Large reservoirs have a beneficial effect upon impure, turbid or discolored water by destroying disease germs, causing turbid waters to settle and become clear, and causing discolored waters to bleach, and the Hetch Hetchy Reservoir might improve the water in these directions; but it is also true that algæ and other minute organisms which are found only in very limited numbers in streams occur in much larger numbers in reservoirs, even though they are fed by the purest spring water or the purest water from mountain streams, and such organisms at times give the water an appreciable taste and odor.

This testimony as to the effect of storing water in the Hetch Hetchy Reservoir, if given by the two experts who were afterward engaged on the Los Angeles supply, is not inconsistent with their views as expressed in the Los Angeles report. If the author had continued his quotation from that report he would have included the following paragraph which relates to the Haiwee Reservoir, located at an altitude of 3 760 feet:

"Although the storage of water in a reservoir has a favorable effect in the directions indicated, it sometimes promotes the growth of water plants or algæ, which make the water less palatable and attractive; these growths are liable to occur with any water, and have very little, if any, sanitary significance. It is not feasible to prevent them, but it is feasible to remove their effects by aëration and filtration."

It should not be inferred from the remarks which the writer has made regarding the quality of the Tuolumne River water

after it has been stored and run through open canals that he believes the water delivered in San Francisco by the works proposed by the author of the paper would not be a first-class water judged by the standard of the water supply of cities throughout the United States. In the present instance, however, a comparison is being made between the relative quality of two supplies, one of which is comparatively near San Francisco and the other at a great distance, and both are hygienically of a very high class, so that it needs a consideration of small differences to determine which is the better water.

The author, still referring to the Los Angeles project, states:

> "The consulting engineers say of this project: 'We find the project admirable in conception and outline, and full of promise for the continued prosperity of the city of Los Angeles.'"

He then asks this question:

> "Compared with Owens River the Tuolumne River is a far more desirable source of supply. Are not, therefore, the same words of praise applicable to the Tuolumne River project in so far as the source of supply and the compared features of the project are concerned?"

This question may be answered to a considerable extent by placing some of the main features of the two projects in parallel columns. The estimates of cost and capacity of the Tuolumne River plan are those given by the author of the paper. It should also be noted that the estimates for the Owens River works are for the portion of the system 226 miles long, extending from the source to the San Fernando Valley, from which the supply of Los Angeles is now taken. A small additional expenditure will be required to convey a part of the water from the end of the aqueduct to filter beds.

	Tuolumne River.	Owens River.
Estimated cost of works, exclusive of distributing system	\$30 724 000	\$24 486 000
Daily capacity (gallons)	60 000 000	258 000 000
Cost of works per million gallons daily capacity	512 067	94 907
Total length of aqueduct (miles)	182	226
Riveted pipe (percentage of whole length)	76	4.8
Method of supply	Constant pumping against head of 625 ft. and pumping in emergencies from Belmont Reservoir.	All gravity.

The Owens River supply for the city of Los Angeles requires a very large expenditure of money in comparison with the size of the city to be supplied, but it is essential that a further water supply should be obtained for this city, and very desirable that it should be obtained without taking water away from the irrigators in Southern California, thereby decreasing the prosperity of that section of the country. It is also desirable that the additional supply should be made so large that the greater part of the water could be used for irrigation, and thereby indirectly increase the prosperity of the city.

It would not have been good engineering to go to so great an expense to obtain a new water supply for Los Angeles had it been possible to obtain at less cost a liberal supply not already in use for irrigation from a nearer source; but as no such source was available, it was a matter of congratulation that the physical conditions between the distant source and the city were such that a great quantity of water could be obtained by gravity, almost wholly through works of a permanent character, so that the annual cost for maintenance, renewals and repairs would be comparatively small. Also that on the line of the aqueduct, comparatively near to the city of Los Angeles, there is a somewhat abrupt fall where electricity can be developed to the extent of 36 000 electrical horse-power for twenty-four hours of the day every day in the year, equivalent to about 80 000 horse-power if concentrated in the working hours of the working days of the year.

The words of praise applied to the Los Angeles project would not be applicable to the Tuolumne River project for two principal reasons: *First*, because it is feasible to provide an ample supply of pure water for San Francisco from nearer sources, by works which would be much more economical, efficient and reliable. This point will be elaborated subsequently. *Second*, because of the unsatisfactory features of the plan for taking water from the Tuolumne River, many of which are inherent in any plan for taking water from this source; namely, the great cost in proportion to the quantity of water which can be made available; the unreliability of a system of so great length, which is made up to a very large extent of pipes under high pressure; the pumping against the unusual head of 625 feet with electricity generated 60 or more miles away, even though "some steam power is to be held in reserve for use in emergency"; and the absence of any large storage of water near the city for use in emergencies, except that contained in a storage reservoir from

which the water has to be lifted at an emergency pumping station.

Leaving now the criticisms made by the author and the comparisons between the Tuolumne project and that for taking water for Los Angeles from the Owens River, and reverting to the engineering questions involved in the water supply of San Francisco, the question which has always stood out with great prominence in the writer's mind is, Why go the great additional distance to the Sierra Nevada Mountains for a supply when an ample quantity of pure water can be obtained comparatively near at hand at a fraction of the cost and by works which will be thoroughly trustworthy and efficient?

The author at several places in his paper indicates his preference for the plan of future water supply for San Francisco which utilizes the established water works and adds thereto as a first enlargement water from the Tuolumne River to the extent that it could be obtained by laying one pipe 48 inches in diameter which would convey 30 000 000 gallons of water, or, possibly, by laying a larger pipe.

Accepting the plan for one 48-inch pipe, it is feasible to make comparisons of the cost of an additional supply of 30 000 000 gallons of water from the Tuolumne River and from the development of local sources delivered at the point where the proposed pipe line crosses Calaveras Creek, about 55 miles from the proposed receiving reservoir in San Francisco.

The author states in his paper that:

> "It seems reasonable to expect that the Calaveras Reservoir will make available about 25 000 000 gallons per day of the 35 000 000 that should flow through or past the reservoir in Calaveras and Hondo creeks. San Antonio Reservoir may bring within reach 4 000 000 out of an average of about 6 000 000 gallons per day."

He therefore thinks it reasonable to expect that 29 000 000 gallons per day can be obtained by the construction of these two reservoirs, and this is only 1 000 000 gallons less than his estimate of the capacity of one pipe line.

It is to be noted that although the mountain water and that from local sources would be brought to the same point, where the pipe line crosses Calaveras Creek, yet the water pressure in the pipe would be that due to a head of several hundred feet.

The writer does not think this additional pressure in the pipe any especial advantage, and if it were so considered it ought also to be noted that the Calaveras Reservoir, which will furnish

25 000 000 gallons per day out of the total of 29 000 000, is considerably nearer San Francisco, measuring along the proposed Tuolumne pipe line, than the point of crossing above mentioned, and it is at such a height as to give more pressure than is proposed for the Tuolumne pipe line.

The cost of conveying water by gravity from Calaveras Reservoir to the city would be less than that of conveying the Tuolumne water by gravity from the crossing above mentioned.

The total cost of the Tuolumne works down to Calaveras Creek, as estimated by the author of the paper, is substantially $19 600 000 for a system with two 48-inch pipes and pumping and power stations of corresponding capacity. If this estimate is diminished by deducting one half of the estimated cost of pipes, pumping and power stations, and of such other portions of the work as can be built on a smaller scale in the beginning and subsequently added to, amounting in all to $7 300 000, but without cutting down the estimate of the cost of the Hetch Hetchy and other reservoirs and of tunnels and canals, the estimate becomes $12 300 000, or, making some allowance for cutting down the size of permanent works, say, $12 000 000.

On the other hand, the writer has estimates of the cost of building the Calaveras and San Antonio dams, which he believes to be liberal, which amount to a total of $4 600 000.

In the case of the Tuolumne system the construction cost per million gallons of capacity for the water delivered at Calaveras Creek is $400 000, while the cost of substantially the same quantity of water obtained by developing the local sources amounts to $159 000.

The author gives a tentative estimate of the ultimate capacity of the Spring Valley Water Company's sources as developed, amounting to 109 000 000 gallons daily, which is well up toward double the quantity of water which he estimated would be required for the city in the year 1950, and substantially the same as the estimate made by the engineer of the Spring Valley Water Company of the probable consumption in that year. It cannot, therefore, be contended that the development of the nearer sources will not meet all of the requirements for a long time in the future.

He stated in a report quoted in his paper, when comparing the Tuolumne River project with the Spring Valley Water Works system, that the latter "ranks first in reliability of service." There is left, therefore, only the alleged superior quality of the mountain water as a reason for much more than doubling the

cost per million gallons of works for obtaining additional water.

Whatever may be the relative merits of a mountain water as compared with that of the nearer sources, the writer believes that there can be no question that the water from the nearer sources, filtered through adequate sand filters, would be more wholesome and more palatable than the water delivered from the mountain sources by the works proposed by the author. The cost of works for such filtration, added to the cost of developing the nearby sources, would not make the total more than $200 000 per million gallons daily capacity, which is just half the estimated cost per million gallons of water delivered at the same point from the Tuolumne River.

The wide difference in the first cost of the works does not by any means tell the whole story. The supply developed by building dams will flow to the common point at Calaveras Creek by gravity, or, if it were desired to convey it by gravity to San Francisco, $\frac{25}{29}$ of the additional supply could be so conveyed, while all of the water from the Tuolumne River would have to be continuously pumped to the great height of 625 feet. The expense for such pumping would be much greater than for the operation of filters and probably would be as great as for the total cost of water filtration, including fixed charges, which is frequently estimated at $10 per million gallons.

In developing the nearer sources the only works to be maintained above the common point mentioned would be the two reservoirs, and in the other case there are works extending for a distance of more than 127 miles, a part of them in a territory difficult of access. The dams would be permanent structures, while the pipe lines, pumping stations and power plants of the Tuolumne project would involve large future outlays for repairs and renewals.

To conclude the discussion of the relative merits of the Tuolumne project and of a project for developing the existing sources: The author concedes that the latter sources are more reliable and that they can be developed to supply all the water required for the next 40 or more years. It is not thought that he will contest the view that the cost of the construction and maintenance of the two dams referred to, including also the construction, maintenance and operation of works for the thorough filtration of the water through sand, will be very much less than the cost of the construction and maintenance of the Hetch Hetchy dam and the building, maintenance and operation of the

works 127 miles in length required to pump the water and convey it to the common point in the Calaveras valley already mentioned.

There is left only the relative quality of the water. It is the writer's contention that the water derived from the Tuolumne source, taken in part directly from streams and in part from a reservoir, and all conveyed through 28 miles of open, unlined canal, will be little if any better than the water from existing sources, and he believes that, by the filtration of that portion of the water taken from existing sources which is not already filtered, a better water can be supplied to San Francisco than the unfiltered water from the Tuolumne source, and for much less than the cost of obtaining water from that distant source.

While the foregoing pages have been devoted to answering criticisms made by the author and to a discussion of his plan for an additional water supply for San Francisco, the writer recognizes that there are many statements in his valuable paper with which he is in complete accord.

Mr. C. E. Grunsky. — The most important requirement relating to the water supply of a municipality is that the water be of good quality. It must be pure and wholesome. This requirement is not yet fully appreciated by the water consumer. The water supplied to many of the larger American cities is not above suspicion and in too many cases it is known to fall far short of the desired standard. No water is entirely satisfactory unless it can safely be used to quench thirst. The general lack of confidence in the water supplied to the larger cities of the Atlantic slope is evidenced by the extensive use of bottled water which, as it reaches the consumer, is attractive in appearance and which the public, though often without adequate guarantee, accepts as safe.

This requirement was not lost sight of in the design of the proposed water works for San Francisco which, as explained in the paper, had to be presented as a project separate and apart from the established privately owned works. It has been pointed out in the official reports on the Sierra supply, as well as in the paper, that the Tuolumne River project would best be carried out as an addition to the present works instead of as a competitive water supply. This point of view rendered it unnecessary to discuss minutely at this time the merits of the Tuolumne River as an independent source of water. It may be stated, however, that when this water was under study by the writer as city engineer, in 1902 and 1903, the conclusion was reached on the basis of appraisements then made and an allowance for

the cost of utilizing the Calaveras Valley properties that the first cost to the city of acquiring the established works with capacity increased to between 50 000 000 and 60 000 000 gal. per day would be about $37 000 000. The Tuolumne River project, with a daily capacity of 60 000 000 gal., was estimated to cost $39 531 000. A complete distributing system was included in both cases.

Since the paper was presented, the question has been submitted to the voters of San Francisco, whether the first step toward the acquisition of municipally owned water works should be taken. The question passed on by the voters related to the issuance of bonds in the sum of $600 000 for the purchase of lands in the Hetch Hetchy Valley and at Lake Eleanor. The voters, at the election which was held on November 12, 1908, endorsed this proposition by a vote of 6 to 1. Still more recently the Spring Valley Water Company, which, prior to the election, had failed to set a price upon its properties at which they might be acquired by the city, has again been asked if it desires to sell its properties to the city. A letter from a committee of the Board of supervisors of the city and county of San Francisco contains the following: "Reduced to a simple statement, the position of the Board of Supervisors is as follows: To proceed without unnecessary delay to the purchase or construction of a water works to be owned and managed by the municipality. In accordance with the provisions of Ordinance No. 505 (New Series) you were so notified. You were given opportunity to offer your properties for sale to the city if you so desired. On September 15, 1908, the Public Utilities Committee directed your attention to ordinance No. 505 (New Series) affording you another opportunity to negotiate with the city. At this time the Water Rates Committee asks the question: Do you wish to sell the properties of the Spring Valley Water Company now used in supplying water to the city and county of San Francisco to the city and county?"

The question is still pending.

How the Tuolumne River water supply project compares with the established water works was set forth by the writer in a report which he made as city engineer under date of November 24, 1902, which has been referred to by Mr. Stearns. The following is from that report:

"It appears from what has been said on the foregoing pages and the earlier reports herein referred to:

"That the Spring Valley Water Works system, to the extent of its capacity, ranks first in the reliability of service.

"That the Tuolumne River project ranks highest in the quality and quantity of water.

"That in the matter of first cost to the city the advantage should be in favor of the Spring Valley system. (A sale at a fair price is to be assumed.)

"It is to be added that in the matter of operation, it remains uncertain which system, the Tuolumne River project or the Spring Valley Water Works, would have the advantage — the probality being in favor of the newer system."

In comparing the cost of water from the Tuolumne River at Calaveras Creek with the cost of impounding water on this creek and on its tributary, the San Antonio Creek, it should be remembered that all of the water from the Tuolumne River at that point, having been pumped over the summit at Altamont, is under pressure sufficient for its delivery in San Francisco.

The Calaveras Valley water, also, is at a sufficient altitude to flow by gravity to San Francisco, but not the water of San Antonio Creek, which would require pumping. The construction of the dams at Calaveras Valley and on the San Antonio Creek would hold back water that now flows into the Suñol gravel beds. How much their construction would decrease the output of these gravels is somewhat uncertain. It may be 5 000 000 to 10 000 000 gal. per day. The unit cost of the new development should, in other words, be figured on the basis of less water than assumed by Mr. Stearns.

He states in this connection that the cost of pumping Tuolumne River water over the summit at Altamont against a head of 625 ft. would probably be as great as "the total cost of water filtration, including fixed charges, which is frequently estimated at $10 per million gallons." For those who wish to analyze this statement it should be repeated that the pumping at Altamont will be with power generated by the water at Bear Gulch and electrically transmitted. The pumping of the San Antonio Creek water would not be so economical.

It is, however, true, in the light of information now at command, that the first cost of developing some of the additional coast range sources would be less than the cost of bringing in water from the more remote Sierra Nevada. The justification for going further for the water lies in the superior quality of the water to be thus obtained and delivered.

Without entering upon a discussion of the quality of the water which San Francisco has been and is to-day receiving, the exceptional purity of the water from the high mountains of the Sierra Nevada is again emphasized in order that it may

be understood why first cost and reliability of service are minor considerations.

The water as it is liberated from the mountain reservoirs, according to every fact now known, will be of prime quality. In this respect, as stated in the paper, the Tuolumne River as a source of supply will differ from Owens River, concerning the water from which the engineers say " that it has a slight turbidity and stain, owing to the drainage from the marshes in Long Valley, and to other return water from the canals and irrigated lands " (of Owens valley). The Owens River water, in other words, is to be improved in transmission to the place of use, while the Tuolumne River water starts pure* and needs no treatment for improvement unless first allowed to deteriorate in transit. The Sierra Nevada Mountains are full of lakes with water appearing crystal clear. Those of the glaciated region under consideration appear exceptionally free from algæ and other plant life. In the water of Lake Tahoe, as stated in the paper, no bacteria were found in three out of four water samples plated on the ground; only one per cubic centimeter in the fourth sample taken nearer shore and only sixty in a sample taken at another time, but rejected for cause. The analysis of Lake Eleanor water is given in the paper. It is not apparent why it should be assumed that water will deteriorate in a Hetch Hetchy reservoir or that such a reservoir will behave like some reservoirs at lower altitudes in other parts of the country instead of like the water bodies already existing in its vicinity. Neither is there any need of discussing the effect that a reservoir of similar capacity would have on an impure turbid water. The water reaching the Hetch Hetchy Valley is not like the water fed into most of the storage reservoirs of the Atlantic slope. The reservoir will not be fed by turbid streams. The material carried in suspension by the incoming waters will be very small.

The seepage loss from a canal planned to come into use without lining is referred to as objectionable. In reply to this criticism of the project, it should be stated, in the first place, that the canal and tunnels can be lined throughout at a moderate cost, but that such lining at the outset was not thought requisite and was not, therefore, included as a feature of the project, nor was it covered by the cost estimate. In the second place, the seepage loss from the canal, except only the last few miles, which are out on the plain between the Tuolumne River and Dry

* See the analysis given in the paper.

Creek, will be return water to the river and available for use of the irrigation districts, whose headworks are lower down on the stream and whose prior rights San Francisco will always respect. In the third place, the canal should, and undoubtedly will, go into service at a flow in excess of the required delivery, so that ordinary seepage loss will not interfere with the delivery of the amount of water required until the time comes when this quantity approaches the canal capacity, and then the canal will be lined. The only seepage that will prove to be a total loss will be that from a few miles of canal below the point where the canal leaves Tuolumne River. This stretch of canal, moreover, will be the only portion of the conduit in which there will be the shallow water which Mr. Stearns has assumed for the full length of the canal.

The canal was not planned with cover throughout because it is located for the most part along a steep, rocky cañon wall and can be made inaccessible to grazing stock throughout its length, but the cover can be added as required. Where crossed by trail or road the canal will, of course, be suitably protected from blowing dust.

The writer does not wish to be understood as having made a strong plea for unlined canals for municipal water supply, and the presentation of a project with any part of the canal unlined is the result of a consideration of local conditions, with due weight given to the added cost of lining the canal.

The portion of the river which will convey the water from the Hetch Hetchy reservoir to the diverting dam is not of the character of an ordinary valley stream. The portions of Tuolumne River, of Eleanor Creek and of Cherry Creek, which are to convey the water from the reservoirs to the diverting dam, lie in deep rock-bound cañons, in which human activities will probably never extend beyond such as relate mainly to a future utilization of these streams for power purposes. Cherry Creek is a high mountain stream whose watershed lies almost entirely within the National Forest reserve, for the most part at elevations of 5 000 to 10 000 ft. This stream is fed by the outflow of numerous glacial lakes, to which artificial reservoirs will, no doubt, be added as the utilization of the water for power becomes of value. It is a stream on which there is not a single resident and on which there never should be any objectionable activity.

Whether a canal only partly lined and partly under cover will be adequate to preserve the high quality of the water, or whether it may be found advisable to keep the water under

cover in lined conduits after diversion from the river, it is confidently believed that from Tuolumne River as a source, water of exceptional quality not requiring treatment can be delivered to San Francisco.

The possibility of expanding the present water works by adding other coast range sources of supply has been admitted. It remains to be added that the presentation of a tentative estimate of ultimate output of the nearby sources of water does not mean that it is certain that these sources can be developed to the indicated limit for use in San Francisco. The estimate is coupled with much uncertainty. It was made, as stated in the paper, to show that the possible expansion of the Spring Valley Water Company's system is not inconsiderable.

ASSOCIATION

OF

ENGINEERING SOCIETIES.

VOL. XLI. AUGUST, 1908. No. 2.

PROCEEDINGS.

Louisiana Engineering Society.

JUNE, 1908. — The Society decided to promote the passage, by the Louisiana Legislature, of a bill to regulate the practice of civil engineering and surveying, and it appointed a Legislative Committee to look after its interest. The bill originated in the Society and was endorsed by the Society in May, 1902, to which reference was made in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES, Vol. XXX, No. 1, for January, 1903; Proceedings of Louisiana Engineering Society, pages 7 and 9.

JULY, 1908. — The following is a copy of the Act passed (No. 308).

Senate Bill No. 135. [By Mr. Favrot.]

AN ACT

TO REGULATE THE PRACTICE OF CIVIL ENGINEERING AND SURVEYING; TO CREATE A STATE BOARD OF ENGINEERING EXAMINERS, AND REGULATE THE FEES AND EMOLUMENTS THEREOF; TO PREVENT THE PRACTICE OF THE SAID CALLINGS OR PROFESSIONS BY UNAUTHORIZED PERSONS; AND TO PROVIDE FOR THE TRIAL AND PUNISHMENT OF VIOLATORS OF THE PROVISIONS OF THIS ACT BY FINE OR IMPRISONMENT; AND TO REPEAL ALL LAWS OR PARTS OF LAWS IN CONFLICT OR INCONSISTENT WITH THIS ACT.

SECTION 1. Be it enacted by the General Assembly of the State of Louisiana, That, from and after the promulgation of this Act, no person excepting those already engaged under existing laws in the practice of Civil Engineering and Surveying, shall practice the said callings or professions within the State of Louisiana, unless such person shall possess all the qualifications required by this Act.

SECTION 2. Be it further enacted, etc., That after the promulgation of this Act, any person before entering upon the practice of Civil Engineering or Surveying shall present to the Board of Engineering Examiners, as hereinafter constituted, a diploma from an engineering college or school of good standing, said standing to be determined by the Board, or shall pass a satisfactory examination before the Board upon the following, to wit:

For Surveying: Geometry, Trigonometry, Land Surveying, Practical Use of Instruments.

For Civil Engineering: Same as surveying; in addition thereto, Natural Philosophy or Physics.

The person shall also satisfy the Board that he is twenty-one years of age, of good moral character, and possess at least a fair primary education. If said diploma or examination are satisfactory to the Board, they shall issue to such person a certificate in accordance with the facts.

SECTION 3. Be it further enacted, etc., That the Engineering Examiners shall consist of a Board of five members, three of whom shall constitute a quorum for the purpose of holding examinations and granting certificates. All members shall be practicing Civil Engineers or Surveyors of good standing. The certificate of the Board shall be conclusive proof of efficiency of the applicant. All examinations held by the Board, and answers of applicants, shall be in writing and shall be filed and kept as records. All members shall be appointed by the Governor of the State from a list presented by the Louisiana Engineering Society, and the Governor shall have the right to remove any or all members thereof for inefficiency or neglect of duty, and to fill all vacancies occurring in the Board from names recommended by the Louisiana Engineering Society.

SECTION 4. Be it further enacted, etc., That the first Board of Engineering Examiners appointed under this Act shall meet and organize within thirty days from the date of their appointment, and shall name one member to serve two years, one to serve three years, one to serve four years, one to serve five years, and one to serve six years, to be decided by lot or agreement among themselves as to their respective terms.

At the expiration of the above terms, each member shall be appointed by the Governor for a term of six years from names recommended by the Louisiana Engineering Society.

SECTION 5. Be it further enacted, etc., That all persons practicing Civil Engineering or Surveying in the State of Louisiana before the passage of this Act shall, within ninety days after its promulgation, register as such practitioners with the Clerk of the District Court of the Parish within which they reside, and, upon the appointment of the Board of Engineering Examiners, shall notify the said Board of such registration.

SECTION 6. Be it further enacted, etc., That to prevent delay and inconvenience, any one member of the Board may grant a permit to practice after a satisfactory examination of any applicant, and shall report thereon to the next regular meeting of the Board. Said temporary permit shall not continue in force longer than until the next regular meeting, and shall in no case be granted less than six months after the applicant has been refused a permit by the Board.

SECTION 7. Be it further enacted, etc., That all certificates issued under Section 2 of this Act must be recorded in the office of the Clerk of the District Court of the Parish in which the applicant resides, who shall make recordation thereof in a book to be kept for this purpose only, and who shall certify to said recordation by endorsement on original certificate, which the holder shall then deliver or transmit to the Board of Engineering Examiners. The fee which the clerk is entitled to charge for such recordation shall be one dollar. Said certificate entitles the holder to be placed on the list of regular Civil Engineers and Surveyors, the publication of which is hereinafter provided for. The Board of Engineering Examiners shall preserve the certificates, and a copy signed by its Secretary shall be received as evidence in courts. Until recordation of said certificate, the holder shall not practice Surveying or Civil Engineering in the State of Louisiana.

SECTION 8. Be it further enacted, etc., That the Board of Engineering Examiners shall publish annually a complete list of registered civil engineers and surveyors, with their residences, in a daily paper of the City of New Orleans, and such published list shall be received as evidence in court that the names it contained are duly registered.

SECTION 9. Be it further enacted, etc., That the members of the Board of Engineering Examiners shall receive in compensation for their duties ten dollars per day during the session of the Board, together with their hotel bills and their traveling expenses by the most direct route to and from their respective residences; the same to be paid out of any

moneys in the treasury of the Board, upon the certificate of the president and the secretary. The Board is empowered to demand a fee of one dollar for issuing a certificate, and ten dollars for examination. If the applicant fails to pass, and no certificate is issued, five dollars of his fee is to be retained. The fee for a temporary permit shall be five dollars, and is to be credited to the applicant when he applies for a permanent permit.

SECTION 10. Be it further enacted, etc., That any person who shall practice or attempt to practice the profession or calling of a civil engineer or surveyor, without having complied with the provisions of this Act, shall be fined not less than twenty-five dollars, not more than one hundred dollars, or shall be imprisoned not less than thirty nor more than ninety days, for each offense by any court of competent jurisdiction.

SECTION 11. Be it further enacted, etc., That the Board may revoke any permit it has issued, when its holder has been convicted of immoral conduct before a competent court.

SECTION 12. Be it further enacted, etc., That this Act shall not apply to the Engineering Departments of the United States, nor to the Civil Engineers and Surveyors of other States and Territories when in actual consultation with registered Civil Engineers or Surveyors of this State, nor to any Civil Engineer or Surveyor of this State actually practicing such profession or calling before the passage of this Act.

SECTION 13. Be it further enacted, etc., That the Board of Engineering Examiners shall make annual report to the Governor of its transactions, with such recommendations for the advancement of the services as it may think best.

SECTION 14. Be it further enacted, etc., That all laws or parts of laws in conflict with this Act be and the same are hereby repealed.

P. M. LAMBREMONT,
Lieutenant-Governor and President of the Senate.

H. G. DUPRE,
Speaker of the House of Representatives.

Approved July 9, 1908.

J. Y. SANDERS,
Governor of the State of Louisiana.

Technical Society of the Pacific Coast.

SAN FRANCISCO, AUGUST 28, 1908. — A regular meeting was held at Blanco's restaurant on O'Farrell Street. About thirty members and guests sat down to a dinner which was served at 6.30 o'clock.

Immediately after the dinner the President, Mr. George W. Dickie, called the meeting to order. The Secretary read the minutes of the last regular meeting of June 5, which were approved.

The President thereupon announced the papers of the evening, as follows:

1. The Use of Asphaltum, by Harry L. Larkin (to be read). 2. The Auxiliary Water Supply of San Francisco, by H. D. Connick (to be discussed). 3. Practical Methods of Fitting up a Hydraulic Mine, by H. A. Brigham (to be read). 4. The Water Supply of San Francisco, by C. E. Grunsky (to be read).

The President announced that the paper by Mr. Larkin would be read at this meeting and its discussion taken up at the next regular meeting of

October, and that the discussion of Mr. Connick's paper would follow the reading of Mr. Larkin's.

Mr. Harry Larkin was called upon and he read an interesting account of "The Use of Asphaltum for Commercial and Practical Purposes."

Mr. Tom W. Ransom began the discussion of Mr. Connick's paper on "The Auxiliary Water Supply of San Francisco." He was followed by the President, Mr. Dickie, who took up a number of the individual features for a general discussion. Mr. Connick responded at length, giving explanations and reasons for the various arrangements that had been considered necessary to meet all the demands of the city. Others followed along the line of the discussion, Mr. Molera, Mr. Morrin and a guest on behalf of the underwriters, who explained certain conditions under which the insurances of the city were greatly reduced.

The meeting was adjourned at eleven o'clock.

Attest,

Otto von Geldern, *Secretary.*

Association of Engineering Societies.

Vol. XLI. **SEPTEMBER, 1908.** No. 3.

PROCEEDINGS.

Engineers' Club of St. Louis.

St. Louis, June 3, 1908. — The 653d meeting of the Engineers' Club of St. Louis was held in the auditorium of the Manual Training School, Von Verson Avenue, near Union Avenue, on Wednesday evening, June 3, 1908, President Brenneke presiding. There were present thirty-eight members and thirty-three visitors, among the latter a large number of ladies.

There being no objection, the minutes of the last meeting were not read.

The application of Mr. Oliver B. Barrows for associate membership, having been duly approved by the Executive Committee, was submitted to ballot, and Mr. Barrows was unanimously elected.

The President then introduced Prof. C. M. Woodward, who presented a very interesting illustrated address on the building of the Eads Bridge. Professor Woodward described in considerable detail the plan adopted for sinking the piers as well as the methods used in erecting the arches. Especial emphasis was laid on the great originality displayed by Captain Eads and his associates in overcoming the numerous difficulties encountered in this pioneer work.

At the conclusion of the address it was voted to extend the thanks of the Club (*a*) to the officers of the St. Louis Electrical Bridge Company and to the Missouri Valley Bridge and Iron Company for the courtesy extended on the occasion of the Club's visit to the McKinley Bridge on May 9; (*b*) to the officers of the St. Louis Portland Cement Company and the Union Sand and Material Company for the hospitable entertainment of May 23, when the Club was invited to visit the plant of the St. Louis Portland Cement Company; and (*c*) to Prof. C. M. Woodward for his kindness in presenting the interesting address on the building of the Eads Bridge, and to the authorities of the Manual Training School for the privilege of holding the meeting of June 3 in the auditorium of that school.

The meeting then adjourned to the dining room of the school, where refreshments, arranged for by the Entertainment Committee, were served.

A. S. Langsdorf, *Secretary.*

Utah Society of Engineers.

SALT LAKE CITY, UTAH, SEPTEMBER 18, 1908. — The regular monthly meeting held in rooms of Commercial Club, Salt Lake City, evening of September 18, was devoted to a discussion of the subject of "Engineering Ethics."

Discussion was opened by Mr. J. C. Hornung, resident engineer of the Salt Lake Public Service Company, and by Mr. R. E. Caldwell, of the Western Engineering Company, and was participated in by Messrs L. C. Kelsey, A. O. Gates, Dr. Lyman, A. P. Merrill, Professor Overstrom, Sidney Bamberger and J. F. Merrill. The discussion was spirited and thorough and a committee was named to investigate the matter and make report as to the advisability of drafting a code applicable to local conditions. There was quite a large attendance of practicing engineers.

The next regular meeting of the society will be held in the Physics building of the University of Utah on the third Friday of October, when a paper will be presented by Mr. R. S. McCaffery, metallurgical director of the Knight Smelter, on the subject of "Connerville and Centrifugal Blowers for Blast Furnaces."

Adjourned.

D. McNICOL, *Secretary.*

Association of Engineering Societies.

Vol. XLI. OCTOBER, 1908. No. 4.

PROCEEDINGS.

Engineers' Club of St. Louis.

St. Louis, September 16, 1908. — The 654th meeting of the Engineers' Club of St. Louis was held at the Club rooms, 3817 Olive Street, on Wednesday evening, September 16, 1908, President Brenneke presiding. There were present sixteen members and six visitors.

The minutes of the 652d and 653d meetings were read and approved. The minutes of the 442d, 443d and 444th meetings of the Executive Committee were read.

The Secretary read an application for membership from Mr. Montgomery Schuyler.

A communication from Messrs. Breed and Hosmer, announcing the donation of Vol. II of their book on the Principles and Practice of Surveying, was read. The Secretary was instructed to make due acknowledgment of the gift.

The resignation of Mr. W. V. N. Powelson as a member of the Executive Committee, due to removal from the city, was read and accepted. The President then called for nominations for the vacancy created by Mr. Powelson's resignation, and Mr. Wall nominated Mr. C. A. Moreno, On motion of Mr. Colnon, duly seconded and carried, the Secretary cast the ballot of the meeting for Mr. Moreno.

The paper of the evening, entitled " Some Details of Gas Distribution," was then presented by Mr. J. D. Von Maur. The distributing mains of the Laclede Gas Light Company of St. Louis were described in detail, with special reference to the means employed to maintain a steady pressure at the service taps; this is accomplished through the use of high-pressure mains which supply the low-pressure mains through reducing valves. One of these reducing valves was exhibited, as well as a specially constructed glass meter arranged to show the mechanism.

A discussion of the paper was participated in by Messrs. W. A. Baehr, H. H. Humphrey, W. G. Brenneke and R. S. Colnon.

Adjourned.

A. S. Langsdorf, *Secretary.*

St. Louis, October 7, 1908. — The 655th meeting of the Engineers' Club of St. Louis was held at the Club rooms, 3817 Olive Street, on Wednesday evening, October 7. President Brenneke presided. There were present thirty-four members and eight visitors.

The minutes of the 654th meeting were read and approved, and the minutes of the 446th meeting of the Executive Committee were read.

Mr. Montgomery Schuyler was elected to membership, and applications were read from the following: Edward Eugene Green (member); Charles Wescott Gennet, Jr. (member); Ernest Linwood Ohle (member); Raymond Glime Alexander (member).

The paper of the evening on the "Electrolysis of Reinforced Concrete" was presented by Prof A. S. Langsdorf. The paper gave the results of two series of tests, twelve specimens having been used in each series. The specimens were connected in series and were subjected to the action of a direct current (0.05 amperes in the first series and 0.2 amperes in the second), which was continued for seventy days in series one and thirty days in series two. In both series there was a loss of weight of the steel which increased in proportion to the time, together with a deterioration and cracking of the concrete. The specimens were placed in earthenware jars and were immersed in fresh water to within half an inch of the top of the concrete.

The paper was discussed and questions were asked by a large number of those present.

Mr. C. A. Bulkeley announced, on behalf of the Entertainment Committee, that an excursion to the new steel plant of Gary, Ind., was being projected by the committee.

Adjourned.

A. S. Langsdorf, *Secretary.*

Boston Society of Civil Engineers.

Boston, June 17, 1908. — At the hour named in the call for the regular meeting this evening, a quorum not being present, the meeting was not called to order.

S. E. Tinkham, *Secretary.*

Bretton Woods, N. H., July 4, 1908. — A special meeting of the Society was held at the Mount Pleasant House, President J. R. Worcester in the chair; twenty-five members and guests present.

In the absence of the Secretary, Mr. Irving T. Farnham was appointed Secretary *pro tem.*

The subject for discussion was, "Why do not Engineers take a more prominent part in public affairs?" The President made the opening address and introduced the following speakers: Mr. George B. Francis, Past President Dexter Brackett, Mr. Morris Knowles and Past Presidents Frank W. Hodgdon and William E. McClintock. After a few closing remarks by the President, the meeting adjourned.

Irving T. Farnham, *Secretary pro tem.*

[The addresses will be printed in an early number of the Journal of the Association of Engineering Societies.]

BOSTON, MASS., SEPTEMBER 16, 1908. — A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.30 o'clock P.M., President J. R. Worcester in the chair; sixty-nine members and visitors present.

The records of the last regular meeting and of the special meeting of July 4 were read and approved.

Messrs. James R. Baldwin, John V. Beekman, Jr., Armand W. Benoit, Harold D. Jones, James M. McNulty, Luis G. Morphy, Alfred W. Parker, Henry B. Pratt, Harry E. Sawtell, and Gilbert Small were elected members of the Society.

Mr. E. W. Howe called attention to the fact that the Board of Harbor and Land Commissioners had no authority by which it could keep on sale the atlas sheets of the map of the Commonwealth prepared by the United States Geological Survey, and suggested that as it has been a great convenience to engineers to be able to purchase these sheets from the board, it would be well to petition the Legislature that authority be given the board to keep a stock of the sheets on sale at all times.

On motion, it was voted to authorize its officers to sign the petition on behalf of the Society.

Mr. Benjamin Fox gave a very full description of a foundation put in by him where cast reinforced concrete piles were used. Mr. Sanford E. Thompson followed with notes of tests which he had made with regard to driving these piles.

Mr. M. M. Cannon, member of the American Society of Civil Engineers, gave a very interesting talk describing the construction of the Steamship Terminals at Brunswick, Ga., and the pier at the Navy Yard, Charleston, S. C., with special reference to the concrete piles used in those structures. Lantern slides were used to illustrate the descriptions given by the speakers.

After passing a vote of thanks to Mr. Cannon for his kindness in presenting the subject before the Society, the meeting adjourned.

S. E. TINKHAM, *Secretary.*

BOSTON, OCTOBER 21, 1908. — A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.35 o'clock P.M., President Joseph R. Worcester in the chair. Fifty-eight members and visitors present.

The record of the last meeting was read and approved.

Messrs. Edward E. Albee, Hermon R. Bliss, Alvin W. King, Charles H. Pease, Ralph E. Rice, Ralph B. Saunders, Albert T. Sprague, Jr., Herman F. Tucker and George S. Whitehead were elected members of the Society.

The President announced the death of Irving T. Farnham, a director of the Society, which occurred on September 19, 1908. On motion of Mr. French, the Chair was requested to appoint a committee of three to prepare a memoir. The Chair appointed as that committee, Messrs. Charles W. Sherman, Henry D. Woods and Charles W. Ross.

The President also announced that a vacancy existed in the office of director for the term expiring in March, 1909, occasioned by the death of Mr. Farnham, and, on motion of Mr. Howe, it was voted that the vacancy be filled at the next meeting of the Society.

Mr. Cowles, for the Committee on Larger Membership and Clubhouse, submitted and read its report.

On motion of Mr. Winslow, it was voted that the report be referred to the next meeting for discussion and that it be printed in the November *Bulletin*.

It was also voted that the thanks of the Society be extended to Mr. Vernon V. Skinner, Penal Commissioner of Boston, for courtesies shown members of the Society on the trip to Deer Island on October 21, 1908.

The President then introduced Dr. Edward V. Huntington, professor of mathematics at Harvard University, who, with the aid of lantern slides, gave a very interesting lecture entitled, " A Study of the Motion of the Gyroscope, with special reference to the Brennan Mono-Rail Car."

Prof. Ira N. Hollis followed with a description of the application of the gyroscope to the Howell Torpedo.

After passing a vote of thanks to Professor Huntington for his interesting lecture on the gyroscope, the Society adjourned.

S. E. Tinkham, *Secretary.*

Sanitary Section.

A regular meeting of the Sanitary Section was held at the Boston City Club, October 7, 1908. Messrs. Gardner S. Gould and Raymond W. Parlin were elected members of the Section.

Mr. Harry W. Clark, chemist of the Massachusetts State Board of Health, gave an interesting account of his observations of sewage disposal works in England and on the continent during a recent trip to those countries. The paper was discussed by Leonard P. Kinnicutt, Earle B. Phelps, Mr. Pitman of the Baltimore Sewerage Commission, and others.

A committee of three was appointed by the Chair to make nominations for a clerk to take the place of Irving T. Farnham, deceased. As a result of the ballot, Robert Spurr Weston was elected Clerk of the Section.

Robert Spurr Weston, *Clerk.*

Report of Committee on Larger Membership and Clubhouse.

Boston, October 21, 1908.

To the Members of the Boston Society of Civil Engineers:

The special Committee on Larger Membership and Clubhouse, which was appointed " to investigate and report upon the question of securing new quarters along the lines outlined in the communication of Mr. L. S. Cowles, of March 18, 1908," begs leave to offer the following report:

CLUBHOUSE.

Your committee deems it desirable for the Society to own a clubhouse, but fears it is not sufficiently strong financially to undertake the acquisition of a suitable property at the present time. With additional funds and a larger membership such a house might be provided and successfully conducted. Its acquisition might be effected by means of the " Permanent

Fund " of the Society, but your committee feels that it would be unwise to recommend such a purchase unless the fund (now about $22 000) amounted to at least 75 per cent. of the total outlay. Further, there should be very favorable prospects of materially increasing the membership in the near future.

From an investigation of property values in Boston, it appears that $50 000 will be required for a suitable property, including necessary alterations. Seventy-five per cent. of this amounts to $37 500, thus requiring an increase of over $15 000 in the Permanent Fund before such a purchase should be attempted. A mortgage of $12 500 would hardly be considered a heavy burden on the property. To increase the Permanent Fund to this extent, and to provide sufficient income to successfully manage affairs after the acquisition of the building, will require a much larger membership than at the present time. While the possession of a permanent home for this Society would doubtless greatly increase the membership, your committee is of the opinion that the Society cannot safely venture upon such an undertaking until such larger membership has been in part secured.

The present quarters offer slight inducement towards increased membership or towards sociability among the present members. Because of this and on account of insufficient finances to acquire a building of our own, your committee would recommend a search for and, if possible, a lease of quarters better adapted to the needs of this Society. It would be advisable to invite the New England Water Works Association and the New England Association of Gas Engineers to coöperate with us in this undertaking. Your committee believes that the plan outlined by a former committee was a step in the right direction, but was too uncertain of attainment, and was handicapped by an unfavorable location (Broad Street). The present committee has so far been unsuccessful in finding a suitable building that offers quarters more desirable than those now occupied by the Society, and recommends that the Special Committee on Quarters be instructed that it is the desire of this Society that more convenient quarters be secured, and that said committee take up the active consideration of this subject and report to the Society at the earliest opportunity.

LARGER MEMBERSHIP.

Inasmuch as a permanent home is desirable and can be secured only through a larger membership, it behooves the Society to take active steps to increase the number of its members. Equally important with the question of more suitable quarters is that of making the Society more attractive to individual members. Increased sociability and a manifest interest of one member in another are needed, both to retain present members and to attract new men. If " the encouragement of social intercourse among engineers and men of practical science " is to continue to be one of the objects of this Society, then more attention should be paid this feature than is being given it at the present time. Better quarters will prove a strong move in this direction.

Efforts should be made to become better acquainted with out-of-town members and to make them acquainted with a larger number of local men. With more convenient quarters, where cards and games might be enjoyed, in addition to the library privileges, the members would surely

experience a certain social intercourse that is now lacking. As a means tending to increase the attractiveness of the Society at the present time, your committee offers the following suggestions:

(1) Establishing a Bureau of Registration for those members seeking employment or a change in position.

Remarks. — While our object as a Society, as set forth in the Constitution, is not necessarily a benevolent one, at the same time a slight effort on our part to aid such members as are unfortunate enough to be temporarily without employment seems only just.

(2) Additional informal meetings, where subjects may be taken up and discussed in a free manner, such discussions not necessarily to be reserved for publication.

Remarks. — The experience of your committee has been that many members are not inclined to enter freely into the discussion at the formal meetings. While this may be due to the proverbial modesty of the engineer, this modesty has been laid aside at many of our informal meetings. These occasions are as a rule largely attended because of their informality and because of the detailed and elementary manner in which the subjects are frequently presented. It is suggested that some of these meetings might acceptably take the form of informal lectures on the elements of various engineering subjects, such as theory of structures, sanitary engineering, reinforced concrete, etc.

(3) Sending our present *Bulletin*, *gratis*, to various large engineering offices in New England.

Remarks. — Such a distribution of our *Bulletin* would certainly be a benefit to the profession at large. The description of current engineering work should prove particularly attractive, as it is the only compilation of that nature of which we are aware. Further, the time of meetings, as well as the subjects to be dealt with, might in this way become known to various engineers, who would otherwise receive such information verbally or not at all. Such distribution would be of additional value to our advertisers whom we must needs depend upon, in a measure, for the success of the publication.

(4) Publication of our proceedings and papers in a journal of our own. This would necessitate our withdrawal from the Association of Engineering Societies.

Remarks. —Your committee fully realizes that this question is a very delicate one, and it is only by examining critically the facts of the case that the above action has been decided upon as being for our best interest. After looking carefully into the financial side of this question, we feel assured that the step advised will not burden the Society with additional financial obligations.

That the foundation of the Association of Engineering Societies was, at the time, a wise proceeding is not to be doubted, and our affiliation with the other societies a right and proper step to take. Conditions have since changed, until our Society now seems to demand a publication more individual in character.

The following table may prove of interest as showing how the various societies comprising the " Association " contributed to Vol. XL of the JOURNAL (January–June, 1908). The figures give the number of pages of reading matter, minutes of meetings not included.

Vol. XL. January–June, 1908.	Boston.	Detroit.	Montana.	St. Louis.	Louisiana.	Pacific Coast.	Total.	Boston.	All Others.	Per Cent. Boston.
January, 1908....	52						52	52		100
February, 1908...	21		33	18	3		75	21	54	28
March, 1908......		31	9			9	49		49	0
April, 1908.......	53			3	10		66	53	13	80
May, 1908........	37						37	37		100
June, 1908.......	21	16	2				39	21	18	54
Vol. XL.........	184	47	44	21	13	9	318	184	134	58

NOTE. — St. Paul and Toledo did not contribute.

From the above it is seen that the Boston Society is practically monopolizing the present publication. We firmly believe that the other societies comprising the Association would benefit by our withdrawal. They would then be obliged to do their full duty toward the publication or see its immediate downfall. It should be noted that two societies have furnished no papers for this volume which contains the winter's proceedings.

Our new publication of, say, ten numbers per annum might well supersede the present *Bulletin*, all papers with discussions to reappear in an annual number, suitably arranged and indexed. Would not many of our members who are not now inclined to spend the time to prepare papers for publication in the journal of the Association, take more interest, and perhaps pride, in furnishing such material for our own publication, thus bringing forward valuable matter that might otherwise not be revealed? The papers of the other societies would still be available in their journal.

(5) That an endeavor again be made to form additional "sections" of the Society.

Remarks. — The recent agitation of this subject, which resulted in the formation of the Sanitary Section, has certainly proved a benefit to the Society. This Section has been a success from the start, and your committee sincerely hopes to witness the formation of a Mechanical Section, and possibly others, at an early date.

(6) Annual meeting of the Society to be made more of a function, so that out-of-town members will have incentive to be present. One entire day to be reserved for the event, with (*a*) the annual dinner on the preceding evening; (*b*) registration and annual meeting in the morning; (*c*) excursion in the afternoon; and (*d*) smoker, with light refreshments, in the evening.

Remarks. — At present the only real stated social function that we enjoy is the annual dinner, and that somehow fails to bring out any considerable portion of the non-resident membership. A meeting as suggested would surely give us a splendid opportunity to meet our non-resident members, and so renew acquaintances and make new ones where it is now impossible. An entire day, say the third Wednesday in March, might be devoted to this function. With the annual dinner occurring on the Tuesday night preceding, most of our New England members could

attend all functions with a loss of but one day from their business. Your committee sincerely hopes that the members of this Society will see fit to inaugurate an annual meeting next March that may prove a lasting pleasure to all who may be fortunate enough to attend.

Luzerne S. Cowles,
Charles B. Breed,
George A. Carpenter,
Ralph E. Curtis,
Committee.

Table showing Growth of Civil Engineering Societies.

Canadian Society Civil Engineers.

January, 1904, 1 145
January, 1908, 2 047 Increase in 4 years = 902, or 79 per cent.

American Society Civil Engineers.

January, 1904, 2 924
January, 1908, 4 411 Increase in 4 years = 1 487, or 51 per cent.

Civil Engineers Club of Cleveland.

March, 1904, 211
March, 1908, 276 Increase in 4 years = 65, or 31 per cent.

Connecticut Society Civil Engineers.

May, 1904, 245
May, 1908, 290 Increase in 4 years = 45, or 18 per cent.

Boston Society Civil Engineers.

July, 1904, 585
June, 1908, 660 Increase in 4 years = 75, or 13 per cent.

British Institute of Civil Engineers.

April, 1904, 7 633
April, 1908, 8 573 Increase in 4 years = 940, or 12 per cent.

Louisiana Engineering Society.

New Orleans, October 12, 1908. — The following resolutions were adopted referring to the death, on October 5, of John Clegg, associate member.

" *Whereas,* It has pleased Divine Providence to take from our midst our esteemed fellow-citizen, John Clegg, associate member of the Louisiana Engineering Society, it is fitting that the members of this Society should express their appreciation of his ability as an attorney-at-law; of his high standing as a judge, and of his devotion to the advancement of all professional studies; therefore,

" *Be it resolved,* That this Society has in the death of Judge Clegg, lost one of its most brilliant and talented associate members, and that a sense of personal loss is keenly felt by every member; and be it

" *Resolved,* That a copy of these resolutions be spread upon the records of this Society, and a copy of same be sent to his bereaved family."

" Alf. F. Theard,
" H. L. Zander,
" W. B. Wright,
" *Committee.*"

Utah Society of Engineers.

SALT LAKE CITY, OCTOBER 16, 1908. — The regular monthly meeting was held on October 16, 1908, in the Physics Building, University of Utah.

Mr. Richard S. McCaffery, lately metallurgical director of the Tintic Smelting Company, gave an interesting talk on " Some Tests on Connerville and Centrifugal Blowers for Blast-Furnace Work."

The subject proved very interesting to the smelter and mine people present, as the employment of centrifugal blowers in smelter operation in the Rocky Mountain region is new practice.

The paper was appreciatively discussed by Messrs. E. B. Bartlett, Prof. G. A. Overstrom and C. F. Moore, chief engineer United States Smelting Company.

The next meeting of the Society will be held November 20 in the Physics Building, University of Utah, when Mr. F. E. Johnson, of the Fairbanks Morse Company, will give an illustrated lecture on " Suction Gas-Producer Plants," and Prof. R. R. Lyman will read a paper on " Quick and Easy Methods of Designing Pipe, and Open Channels for Carrying Water."

Adjourned.

D. McNICOL, *Secretary.*

Association of Engineering Societies.

Vol. XLI. NOVEMBER, 1908. No. 5.

PROCEEDINGS.

Engineers' Club of St. Louis.

St. Louis, October 21, 1908. — The 656th meeting of the Engineers' Club of St. Louis was held at the Club rooms, 3817 Olive Street, on Wednesday evening, October 21, President Brenneke presiding. There were present twenty-nine members and four visitors.

The minutes of the 655th meeting were read and approved. The minutes of the 447th meeting of the Executive Committee were read.

The Secretary read a letter from Mr. S. Bent Russell announcing the presentation to the Club of a set of reports of the Board of Public Improvement of St. Louis.

An application for membership was read from Mr. John T. Garrett.

The following were elected: Raymond Glime Alexander (member), Charles Wescott Gennett, Jr. (member), Edward Eugene Green (member), Ernest Linwood Ohle (member).

Mr. C. A. Bulkeley, chairman of the Entertainment Committee, made a statement of the plans for the trip to Gary, Ind. On the suggestion of Mr. W. A. Layman, the Secretary was instructed to write to the Secretary of the Western Society of Engineers, informing him of the proposed trip.

The paper of the evening, on "The New Seven-Foot Steel Flow Line from Baden to the Chain of Rocks," was presented by Mr. W. H. Henby. The paper gave a good description of the plans and construction of the flow line, illustrated by numerous slides, and included a summary of the cost of the work.

The discussion that followed the reading of the paper was participated in by a large number of those present.

Adjourned.

A. S Langsdorf, *Secretary.*

St. Louis, November 4, 1908. — The 657th meeting of the Engineers' Club of St. Louis was held at the Club rooms on Wednesday evening, November 4. Vice-President E. E. Wall presided. There were present twenty-two members and two visitors.

The minutes of the 656th meeting were read and approved and the minutes of the 448th meeting of the Executive Committee were read.

Mr. John T. Garrett, on ballot, was elected to membership.

Applications for membership were read from the following: W. A. Heimbuecher, C. B. Lord.

The Secretary read a letter from Mr. Richard McCulloch, inviting members of the Club to inspect a section showing different methods of paving T-rail track, this exhibit being installed at the Park and Van Deventer office of the United Railways Company. A letter was also read from Miss Mary Klemm, librarian in the Academy of Science, announcing that the Academy desired to secure a tenant for one of the rooms in the building.

The following were nominated for the Nominating Committee: C. W. Childs, Edward Flad, R. L. Murphy, William Elliott, A. L. Jacobs.

A motion, duly seconded, to close the nominations was carried. It was unanimously voted that the rules be laid aside and that the Secretary cast the ballot of the meeting for the election of the Nominating Committee as above constituted.

Mr. W. W. Horner then presented the paper of the evening on the "Design and Constructional Features of the Harlem Creek Sewer." The paper described in detail the various sections adopted for different parts of the sewer, and included a description of the constructional methods employed on various parts of the work. The paper was freely illustrated by numerous lantern slides.

The discussion was participated in by Messrs. B. H. Colby, E. E. Wall, W. S. Henry, A. P. Greensfelder and R. H. Phillips.

Adjourned.

A. S. Langsdorf, *Secretary*.

Technical Society of the Pacific Coast.

San Francisco. — Regular meeting held Friday, November 6, 1908, President George W. Dickie in the chair. The meeting was called to order immediately after dinner, which was had at the Argonaut Hotel, about twenty members being present. The minutes of the last regular meeting of the Society were read and approved.

The Secretary read the following applications for membership, which were ordered to take the usual course: George Fisher Beardsley, metallurgist, Fruitvale, Cal.; J. W. White, electrical engineer, Atlas Building, San Francisco.

The Secretary read the following letter, which he explained as having been written after hearing of the death of Mr. George E. Dow, who died in Berlin in the middle of October.

San Francisco, October 19, 1908.

To the George E. Dow Company,
San Francisco:

Sirs, — The Technical Society has heard with great regret of the death of Mr. George E. Dow, one of its most esteemed members, and the

Secretary has been instructed to communicate with you and to offer to the family and to those nearest and dearest to him the expressions of deepest sympathy.

It seems particularly unfortunate that Mr. Dow should die at a time when in the rehabilitation of this great city a man of his type and energy could least be spared. He was in the prime of his life, and his useful career should not have been ended for many years to come. To close it suddenly, when not yet sixty years of age, is tragic and much to be lamented.

Expressing again the sympathies of all his engineering colleagues to his family and business associates, I am, for the Society, as well as on my own behalf,

Yours faithfully,
(Signed) OTTO VON GELDERN, *Secretary.*

The action of the Secretary in this matter was approved, and he was instructed to communicate with the relatives of the late Mr. Dow for the purpose of obtaining data to write a suitable memorial for publication in the JOURNAL.

The members present thereupon chose the following Nominating Committee to prepare a ticket of officers for the ensuing year, and to submit it to the Society at the time of the next regular meeting of January: H. A. Brigham, chairman; Heinrich Homberger, Leon S. Quimby, Harry Larkin and L. S. Griswold.

Mr. Beardsley thereupon discussed the paper presented at the last regular meeting by Mr. Harry Larkin on the "Use of Asphaltum," dwelling on the use of coal tar in Australia for similar purposes, and Mr. Larkin addressed the Society further on the same subject in explanation of the commercial value of the proper product, emphasizing the fact that coal tar will penetrate to some extent and that asphaltum is nothing more or less than a protective coating or blanket without penetrating qualities.

The paper by Mr. H. A. Brigham, read by title at the last regular meeting, on the subject of "Methods of Hydraulic Mining," was taken up. The President read the paper by extracts, dwelling upon the individual features of the subject sufficiently to establish the points of the author. The paper proved an extremely interesting one, as it brought up the old methods of gold washing that had not been discussed by the Society for many years, and this aroused an interest in the older members who had had more or less acquaintance in their day with hydraulic mining.

Mr. W. W. Waggoner, of Nevada City, discussed the paper by letter from the standpoint of the hydraulic miner. The letter was read by the Secretary, after which a general discussion took place.

The members presented a vote of thanks to the author, Mr. Brigham, for his very detailed and exhaustive paper, which, when published, will tend to perpetuate the valuable practical experiences of an old hydraulic miner.

The meeting thereupon adjourned to meet in January, 1909.

OTTO VON GELDERN, *Secretary.*

Utah Society of Engineers.

SALT LAKE CITY, UTAH, NOVEMBER 20, 1908. — The November meeting was held in Physics Building, University of Utah. There were about thirty local engineers present, and a highly interesting and instructive paper was presented by Mr. F. E. Johnson dealing with "Gas Producer Plants." Slides were shown, picturing suction producers in the making and in their various applications as prime movers. Dr. R. R. Lyman gave a short but valuable talk on "Quick and Easy Methods of Designing Pipe and Open Channels for Carrying Water."

The diagrams of Professor Church were illustrated as applied in the solving of water channel problems.

Three applications for membership were presented and acted upon favorably, the gentlemen admitted being Mr. R. E. Jerrault, Wm. A. Black and Leonard Wilson.

Messrs. E. A. Wall and L. E. Riter were named as the Society's representatives to attend the National Mining Congress at Pittsburg.

As authorized at the September meeting, President Merrill appointed the following-named gentlemen to act as a committee to consider the question of "Ethics" and to report their recommendations to the Society at a later meeting: H. P. Saunders, Ben. F. Tibby, Prof. G. A. Overstrom, R. E. Caldwell, Sidney Bamberger.

ASSOCIATION
OF
ENGINEERING SOCIETIES.

VOL. XLI. DECEMBER, 1908. No. 6.

PROCEEDINGS.

Engineers' Club of St. Louis.

ST. LOUIS, NOVEMBER 18, 1908. — The 658th meeting of the Engineers' Club of St. Louis was held at the Club rooms on Wednesday evening, November 18, 1908. President W. G. Brenneke presided. There were present about thirty-five members and twenty-five visitors, of whom many were ladies.

In calling the meeting to order, the President stated that the Executive Committee had decided to make the meeting take the form of an open one, in celebration of the fortieth anniversary of the first meeting of the Club, which occurred in November, 1868. He referred to the past history of the Club and bespoke for it a continued growth in membership and influence.

On motion, duly seconded, it was voted to dispense with the usual order of business, with the exception of the report of the Nominating Committee which was due to be presented at this meeting, according to the provisions of the By-Laws. The Secretary then read the following letter which had been received from the Chairman of the Nominating Committee:

ST. LOUIS, November 16, 1908.

MR. A. S. LANGSDORF,
SECRETARY ENGINEERS' CLUB OF ST. LOUIS,
3817 OLIVE STREET, CITY.

Dear Sir, — The Nominating Committees, having selected one candidate for each office for the ensuing year, as is provided in Section No. 11 of the By-Laws, hereby report to the Club their selections as follows:

President — E. E. Wall.
Vice-President — R. S. Colnon.
Secretary and Librarian — A. S. Langsdorf.
Treasurer — E. B. Fay.
Two Directors — C. A. Moreno and Carl Gayler.
Three Members of the Board of Managers of the Association of Engineering Societies — O. W. Childs, J. T. Dodds, Samuel Trepp.

Respectfully yours,

O. W. CHILDS,
EDWARD FLAD,
R. L. MURPHY,
WILLIAM ELLIOTT,
A. I. JACOBS,
Nominating Committee.

Per O. W. CHILDS, *Chairman.*

The President then introduced the speaker of the evening, Prof. Holmes Smith, of Washington University, who adressed the meeting on the subject "Constructional Features of the Gothic Cathedrals." The speaker traced the development of the finest examples of Gothic cathedral architecture from the early Roman Christian churches, which, in their turn had been developed from the prevailing style of Roman architecture for dwelling purposes. It was shown how, as the churches increased in size, the roof was changed from the ordinary flat timber construction to the semi-circular stone arch, then to the pointed arch, and finally to the groined arch. In this connection it was also shown how the lateral support for the arches gradually developed from a crude form of barrel vault to the graceful flying buttress. The address was very freely illustrated by lantern slides.

At the conclusion of the address the meeting adjourned to the adjoining rooms where refreshments were served.

A. S. Langsdorf, *Secretary.*

St. Louis, December 2, 1908. — The annual meeting of the Engineers' Club of St. Louis was held at the Club rooms on Wednesday evening, December 2, 1908, at 8.30 o'clock, Vice-President E. E. Wall presiding. There were present twenty-one members and one visitor.

The minutes of the 657th and 658th meetings were read and approved. The minutes of the 449th, 450th and 451st meetings of the Executive Committee were read.

The following applications were presented: Wahlers, Ernest A. C. (associate member); Davis, W. Harding (associate member).

The following were elected: Heimbuecher, W. A. (member); Lord, C. B. (associate member).

The chairman announced that additional nominations for officers might be made by written request signed by five members. No such additional nominations were made, thus leaving the nominations for the different offices as follows:

For President — E. E. Wall.
Vice-President — R. S. Colnon.
Secretary and Librarian — A. S. Langsdorf.
Treasurer — E. B. Fay.
Directors — C. A. Moreno, Carl Gayler.
Members Board of Managers, Association of Engineering Societies — O. W. Childs, J. T. Dodds, Samuel Trepp.

Annual reports were then presented by Mr. W. G. Brenneke, chairman of the Executive Committee; Mr. A. S. Langsdorf, secretary; Mr. O. F. Harting, treasurer; Mr. A. S. Langsdorf, librarian; Mr. R. L. Murphy, chairman of the Board of Managers; Mr. C. A. Bulkeley, chairman of the Entertainment Committee, and Mr. A. O. Cunningham, chairman of the Membership Committee. All of the reports were received and filed. The chairman stated that the report of the Treasurer would be further considered by the Executive Committee and audited according to the usual practice.

Adjourned.

A. S. Langsdorf, *Secretary.*

St. Louis, December 16, 1908. — The annual dinner of the Engineers' Club of St. Louis was held on Wednesday evening, December 16, 1908, at 7.30 P.M., at the Mercantile Club. There were present thirty-three members and seven guests. Among the latter, four were guests of individual members, and three, namely, Mr. Arthur N. Sager, Prof. C. A. Waldo and Dr. David Franklin Houston, were the guests of the Club.

At the conclusion of the dinner President W. G. Brenneke announced that as a result of the letter ballot for the election of officers the following had been elected:

President — E. E. Wall.
Vice-President — R. S. Colnon.
Secretary and Librarian — A. S. Langsdorf.
Treasurer — E. B. Fay.
Directors — C. A. Moreno, Carl Gayler.
Board of Managers, Association of Enginneering Societies — O. W. Childs, J. T. Dodds, Samuel Trepp.

Mr. Brenneke then introduced the new President, Mr. E. E. Wall, who then presided as toastmaster.

The following addresses were made:

Address of the retiring President, William G. Brenneke, "Lessons Taught by the Failure of the Quebec Bridge"; "The Need of Engineers in Municipal Government," Samuel Trepp; "Mathematics and the Engineer," Prof. C. A. Waldo; "The Engineer Citizen," A. P. Greensfelder; "The Law and the People," Arthur N. Sager.

At the conclusion of the regular addresses, Chancellor David F. Houston, of Washington University, was called on for a few remarks, and responded informally.

Adjourned.

A. S. Langsdorf, *Secretary.*

Boston Society of Civil Engineers.

Boston, November 18, 1908. — A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.35 o'clock P.M., President Joseph R. Worcester in the chair. Sixty-one members and visitors present.

The record of the last meeting was read and approved.

Messrs. Edwin F. Allbright, Henry M. Chadwick, John E. Cunningham, Oliver W. Hartwell, Howard B. Loxterman, Rolf R. Newman and Richard H. Rich were elected members of the Society.

Mr. Frederic H. Fay was elected a Director of the Society for the term expiring in March, 1909.

Mr. C. W. Sherman for the committee appointed to prepare a memoir of our late associate, Irving T. Farnham, presented and read the report of that committee.

The Secretary announced the deaths of two members of the Society, G. Edward Sleeper, who died October 25, 1908, and Arthur W. Hunking, who died November 12, 1908.

By vote of the Society, the President was requested to appoint committees to prepare memoirs. The President has appointed as these committees the following members: On memoir of Mr. Sleeper, Mr. Frank O. Whitney; and on memoir of Mr. Hunking, Mr. Frank S. Hart.

An invitation was read from the Secretary of the First New England Conference called by the governors of these states, inviting members of this Society to be present at the meetings to be held in Boston on November 23 and 24, at which the following topics will be considered: Tree Planting, Protection and Promotion of Supplies of Sea Food, and Highways and Their Use.

The report of the Committee on Larger Membership and Club House presented at the last meeting was then taken up for discussion, and on motion of Mr. Hodgdon, the report was accepted. On motion of Mr. Winslow it was voted to consider the recommendations of the committee *seriatim*.

It was moved and duly seconded that the following recommendation of the committee in relation to a club house be adopted: "That the Special Committee on Quarters be instructed that it is the desire of this Society that more convenient quarters be secured and that said committee take up the active consideration of this subject and report to the Society at the earliest opportunity."

Mr. Thompson moved the following amendment: "The committee is further instructed to confer with the officials of the New England Water Works Association, the Society of Gas Engineers, the Section of Institute of Electrical Engineers, the Boston Society of Architects, the Boston Architectural Club, and any other societies interested, with a view to combining the quarters of these various societies." After considerable discussion the amendment was adopted.

At this point the President called attention to the by-law requiring the literary exercises "to begin not more than a half hour after the meeting is called to order," and ruled that business must be suspended.

After the literary exercises, the discussion of the report of the Committee on Larger Membership and Club House was resumed, the question being on the adoption of the recommendation of the committee in relation to a club house as amended by the meeting.

Mr. E. H. Gowing offered the following motion as an amendment in substitution for the question before the meeting:

Voted: That the Committee on Larger Membership and Club House be continued and instructed that it is the earnest desire of the Society to acquire a permanent home or club house at the earliest feasible time; that the Society desires the committee to confer with the New England Water Works Association, the Architectural Societies, the Gas Engineers, the Railway and Railroad Clubs, and any other association which may be suggested or which, in their opinion, might be desirable to have coöperate with this Society in securing a suitable building; that the committee carefully investigate the question of financing a building or club house, and report at length as soon as possible.

A general discussion followed, and at its conclusion the amendment was adopted. A vote was then taken on the original motion as amended, and it was carried.

The consideration of the second portion of the report of the committee

in relation to larger membership was then taken up, and after considerable discussion it was finally voted, on motion of Professor Breed, that this portion of the report be considered at a special meeting of the Society to be called by the President.

The literary exercises of the meeting consisted of a very interesting and instructive paper by Mr. J. G. Callan, of the General Electric Company, entitled, "The Small Steam Turbine considered from an Engineering and Commercial View-Point." The paper was very fully illustrated by lantern slides and a 5-kw. Curtis single stage horizontal condensing steam turbine was also exhibited.

A discussion followed in which Messrs. F. W. Dean, W. H. Herschel and others took part.

After passing a vote of thanks to Mr. Callan for his valuable paper, the Society adjourned.

S. E. Tinkham, *Secretary.*

Boston, Mass., December 11, 1908. — A special meeting of the Boston Society of Civil Engineers was held at the Boston City Club, 9 Beacon Street, Boston, at 7.45 o'clock p.m., Vice-President Henry F. Bryant in the chair. Fifty-one members present.

The chairman announced that the meeting had been called by the President, in accordance with a vote of the Society passed at the last meeting, to consider the suggestions in relation to a larger membership made in the report of the Committee on Larger Membership and Club House presented at the October meeting, and to act upon the same or any modifications thereof.

The six suggestions offered in the report were then fully and freely discussed. The Secretary read a communication from Mr. George B. Francis and other members of the Society in New York City, from Mr. Laurence Bradford, from Edwin F. Dwelley and from Mr. Andrew D. Fuller, bearing on the subject under discussion. The last two communications were by vote referred to the Committee on Larger Membership and Club House.

Action was taken on the six suggestions as follows:

Suggestion 1. Establishment of a Bureau of Registration. *Voted:* That it is the sense of this meeting that a bureau of registration for members seeking employment or a change of position should be established by this Society and that the Committee on Larger Membership and Club House be instructed to formulate a plan for the establishment of such a bureau and report the same to the Society.

Suggestion 2. Additional Informal Meetings. After an explanation of what the Board of Government is doing in relation to these meetings, no action was taken.

Suggestion 3. Increased Circulation of the *Bulletin.* It was voted that the Board of Government be requested to send the *Bulletin* gratis to such of the larger engineering offices as it deems expedient.

Suggestion 4. Publication of the Proceedings and Papers of the Society in a journal of its own. After a very free discussion of this suggestion, it was voted to lay the matter on the table.

Suggestion 5. Formation of Additional Sections of the Society. The following resolution was adopted: *Resolved,* That this meeting favors the

formation of additional sections and respectfully suggests to the Board of Government the possibility of creating more active interest in the Society by the appointment of certain committees to investigate and report to it upon the feasibility of forming additional sections.

Suggestion 6. Annual Meeting to be made more of a function. *Voted:* That the Society approves the recommendation of the committee, and that the matter of arranging for the annual meeting be referred to the Board of Government with full powers.

Adjourned.

S. E. Tinkham, *Secretary.*

Boston, Mass., December 16, 1908. — A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.40 o'clock P.M., President Joseph R. Worcester in the chair. One hundred and ten members and visitors present.

The records of the last regular and the special meeting of December 11, 1908, were read and approved.

Mr. John G. Andrews was elected a member of the Society.

The Secretary announced the death of Charles D. Elliot, a member of the Society, which occurred December 10, 1908, and by vote the President was requested to appoint a committee to prepare a memoir. The President has appointed as that committee Messrs. G. A. Kimball, J. A. Holmes and C. A. Pearson.

The Secretary reported for the Board of Government that it had appointed Mr. H. K. Barrows a member of the Committee on Excursions in place of Mr. E. M. Blake, resigned, and Mr. E. S. Larned a member of the Committee on Larger Membership and Club House in place of Mr. C. R. Gow, resigned.

A series of papers was then presented and read under the general title, "Boylston Street Bridge, Boston, from 1888 to the present time; the destruction and reconstruction of a bridge subjected to locomotive fumes and increasing car loads."

Mr. Frederic H. Fay described the design and construction of the original bridge built in 1888; Prof. Chas. M. Spofford followed with an account of the strengthening of the bridge in 1907 for the Boston Elevated Railway Company; Mr. Fay then described the rebuilding of the bridge in 1908 for street traffic, and Mr. John C. Moses gave an account of the erection work in connection with the rebuilding of both portions.

All the papers were fully illustrated with lantern slides. A general discussion followed.

Adjourned.

S. E. Tinkham, *Secretary.*

Sanitary Section.

A special meeting of the Sanitary Section of the Boston Society of Civil Engineers was held at the Boston City Club on Wednesday, December 2, at 7.30 P.M. Mr. J. Pickering Putnam read a paper entitled, "Some Anomalies in Modern Plumbing Regulations." This paper was illustrated with lantern slides. Mr. David Craig, President of the Master

Plumbers' Association; Mr. James C. Coffey, Executive Officer of the Worcester Board of Health; Mr. Charles R. Felton, City Engineer of Brockton, and others took part in the discussion.

Thirty-three members and guests were present.

The next meeting will be held in February.

ROBERT SPURR WESTON, *Clerk.*

Montana Society of Engineers.

BUTTE, MONT., NOVEMBER 14, 1908. — The regular meeting of the Society for the current month was called to order at the usual time and place, Vice-President C. H. Bowman presiding. The minutes of the October meeting were submitted and approved. Charles Henry Schmalz was elected to active membership in the Society. The following resolutions on the death of Messrs. Abbott and Beckler were read and endorsed.

Resolutions on the death of A. A. Abbott:

Whereas, In the death of A. A. Abbott the Montana Society of Engineers has suffered a great loss, and desiring to place on record its appreciation of his high character, both as an engineer and as a man, and of his conscientious discharge of every duty intrusted to him; therefore, be it

Resolved, That this Society shall express, by these resolutions, its sincere sorrow on the death of Mr. Abbott, and these resolutions shall be spread upon the minutes of the Society and a copy forwarded to his bereaved family.

J. C. ADAMS,
B. H. DUNSHEE,
C. H. MOORE,
Committee.

Resolutions on the death of Mr. E. H. Beckler:

Whereas, Death has claimed Mr. E. H. Beckler, a charter member of the Montana Society of Engineers, and a former president of the Society,

Be it resolved, That the Montana Society of Engineers does hereby condole with the whole engineering profession in the loss of a thorough engineer and a true man, and that in order to respect the memory of Mr. Beckler this resolution be spread upon the minutes of the Society and a copy be furnished to surviving members of his family.

JOHN GILLIE,
EUGENE CARROLL,
FRANK L. SIZER,
Committee.

BUTTE, MONT., November 11, 1908.

On motion, it was decided to hold the next annual meeting at Great Falls, Mont., January 7–8–9, 1909, and President Wheeler was requested to name a Committee of Arrangements to prepare a program for that event. The Secretary was instructed to prepare obituary notices respecting Messrs. Abbott, Baker and Beckler for publication in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES. Mr. J. H. Harper gave his views on the duties of the State Engineer with particular reference to the supervision and approval of the construction of power dams in Montana by said official. The Committee on Nomination of Officers for the ensuing year not being able to report, the meeting was adjourned to Saturday evening, November 21.

CLINTON H. MOORE, *Secretary.*

ADJOURNED MEETING.

BUTTE, MONTANA, NOVEMBER 21, 1908. The meeting was called to order by Vice-President Bowman. Quorum present.

The following resolutions on the death of John S. Baker were presented and approved.

Resolutions upon the death of Mr. John S. Baker:

Whereas, The Montana Society of Engineers is again called upon to mourn the loss of one of its most earnest members, Mr. John S. Baker, an engineer of marked ability in his chosen branch of the profession, and a man of sterling integrity and high character in all his dealings with his fellowman; and

Whereas, While he was physically afflicted in such a way as to render the outdoor life of the engineer probably very burdensome and wearying at times, yet he never complained, but always held up his end in a way that should stand as an example to the young men of the profession who have hard tasks thrust upon them but have no physical impediments to in any way hinder their accomplishment; and

Whereas, It is most fitting that this Society should take notice of its loss and should make some record of it; therefore, be it

Resolved, That in the death of Mr. John S. Baker, the Montana Society of Engineers has lost one of its most talented members, and the state of Montana, an engineer of marked ability, who, had he lived, would have rendered our grand state much valuable service in the development of its natural resources now lying dormant, awaiting but the help of capital and the skill of the engineers to bring them into activity and usefulness. Be it further

Resolved, That this Society expresses its sorrow to the relatives of our departed brother, and that a copy of these resolutions be sent to them and another copy be spread on the minutes of the Society.

Respectfully submitted,

ROBERT H. LINDSAY, JR.,
JOHN D. POPE,
ROBERT A. MCARTHUR,
Committee.

The Committee on Nomination of Officers for the Society for 1909 presented the following list and it was approved:

President — Charles H. Bowman.
First Vice-President — Frank M. Smith.
Second Vice-President — F. W. C. Whyte.
Secretary and Librarian — Clinton H. Moore.
Treasurer and Manager of Board — Samuel Barker, Jr.
Trustee — Theo. Simons.

Respectfully,

EUGENE CARROLL,
GEO. E. MOULTHROP,
W. T. BURNS,
Committee.

The Secretary was instructed to circulate the ballots for the same. Messrs. Goodale and Moore were appointed a Committee on Transportation.

Adjournment.

CLINTON H. MOORE, *Secretary.*

BUTTE, MONTANA, DECEMBER 12, 1908. — The usual meeting for the month was called to order on the above date at 8 P.M. Vice-President Chas. H. Bowman presided. After the reading and approval of the min-

utes of the November meetings, the Secretary presented the applications of the following candidates for membership in the Society: James A. Bow, Arthur Crowfoot, Archibald T. Elliott, David M. Folsom, Charles O. Jenks, George Kuehner, Charles E. Livers, Leon M. McAllister, Charles E. Rowe and Peter Thill. These applications being approved, the Secretary was instructed to prepare the usual ballots. Messrs. Frank D. Jones and Frank Scotten were reinstated. Obituary notices on the death of A. A. Abbott and John S. Baker were read by the Secretary and were recommended for publication in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES. Further time was granted for a like notice on the death of E. H. Beckler. The Committee on Transportation made a brief report, not definite, on account of lack of final reply from Great Northern Railway officials. After a very interesting account by Vice-President Bowman of his observations at the late Mining Congress, held at Pittsburg, Penn., adjournment followed.

CLINTON H. MOORE, *Secretary.*

Utah Society of Engineers.

SALT LAKE CITY. — Society met in main dining room of Commercial Club, Salt Lake City, Friday evening, December 18, and the evening was celebrated as an "Engineering Smoker," there being about forty members present.

Dr. W. C. Ebaugh, Ph.D., of the State University, delivered a highly instructive and interesting address on "Smelter Smoke Treatment," minutely describing the construction and operation of the various methods of "treatment" employed or tested by the smelters of the Inter-Mountain region.

Mr. Richard S. McCaffery, until recently metallurgical director of the Tintic Smelter, read an original paper dealing with "Blast Furnace Operation," especially with regard to the constitution and formation of slag.

Both papers were thoroughly discussed by the members present and a unanimous vote of thanks was tendered the two members presenting papers.

The next meeting will be held in the Physics Building, State University, January 15, when a paper will be presented by Mr. Leonard Wilson, resident manager for the General Electric Company, dealing with "Transformer Substations," and Prof. E. H. Beckstrand will deliver an address on "Testing of Materials."

D. MCNICOL, *Secretary.*